SCIENCE ACTIVITIES

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Mark Goresky
A Graduating Gift June/1963
Grandpa & Grandma

Drawings by ROBERT KUNZ


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Science Activities 2

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Preface

Science plays an increasingly important part in modern life. Consequently, activities related to science should have an important place in school curricula. Whether science activities are effective or not, however, depends upon the teaching methods employed. The authors have written this book with the hope that it will assist in making science interesting and vital to many boys and girls.

This textbook, *Science Activities, Book Two,* has been written around the central theme: *Science enables us to improve our ways of living and working with others in our social environment through the improved use of the forces of nature, through better food production from domestic animals, and through an understanding of the animal kingdom and of means of conserving our heritage of wildlife resources.* In keeping with the general theme, a study is made of the causes of depletion and of practical methods of conserving Canada's wildlife resources. Also in keeping with the general theme, the improved use of the forces of nature is studied in relation to navigation, transportation, communication, domestic use of electricity, and weather forecasting.

A second book, *Science Activities, Book One,* has been prepared around the theme: *Man makes use of science to help him use and change his natural environment to satisfy his basic needs, such as food and water, warmth, clothing, and shelter.*

Science involves two aspects: *useful content* (what to learn) and *scientific method and attitudes* (how to think). Throughout the *Science Activities* textbooks, both aspects have been kept in mind and emphasized in the selection of material and in the method of presentation.

Each topic is approached through problems and activities which encourage the pupils to launch out for themselves and to gather information by means of their own investigating, observing, experimenting, and reading. The books then present subject matter to support and supplement what the pupils have learned as a result of their work and thinking.

A seasonal approach (fall, winter, and spring) has been followed where applicable so that, at the time each unit is likely to be undertaken, materials for study are available, and appropriate activities and observations can be carried on.

At suitable intervals in each unit are questions and exercises designed to focus attention on the general theme of each book, and to test the pupils' knowledge and understanding as well as their progress in the use of the scientific method and in the development of scientific attitudes.

Each unit concludes with a test that will review what has been learned and in addition will test the pupils' ability to apply their knowledge in specific situations.

The books provide science experiences suitable for the majority of the pupils in each class, and include, as well, problems and activities for pupils with special interests and abilities.

Further statements regarding the organization and philosophy of the *Science Activities* textbooks are explained to the pupils in the introduction "Making a Good Beginning."

— T. W. H.
— H. C. A.
— H. G. H.

Contents

W. Stone

I trust in Nature for the stable laws
Of beauty and utility.

—*Robert Browning*

MAKING A GOOD BEGINNING

Two thousand years ago, people believed that horse hairs in water grew into snakes. They accepted the belief without question. If they had known how to experiment as we do today, how could they have tested such a belief? What is an experiment? Some people believe that carrying a rabbit's foot in the pocket will bring good luck. Is this merely a superstition, or can it be proved? What is the difference between superstition and scientific fact?

TWO THOUSAND YEARS AGO, sailors mutinied when their captains sailed too far out to sea. They believed that the earth was flat, and they were afraid that they might come to the edge of the world and fall off. We would laugh at their fears today. We would laugh, too, if someone told us that living things could grow out of dead things. Yet 2000 years ago, people thought that frogs grew from mud at the bottoms of ponds and that flies and maggots grew from meat. We can laugh at these ideas today, because science has taught us that they are false. It has proved that the earth is round, and that living things can grow only from other living things.

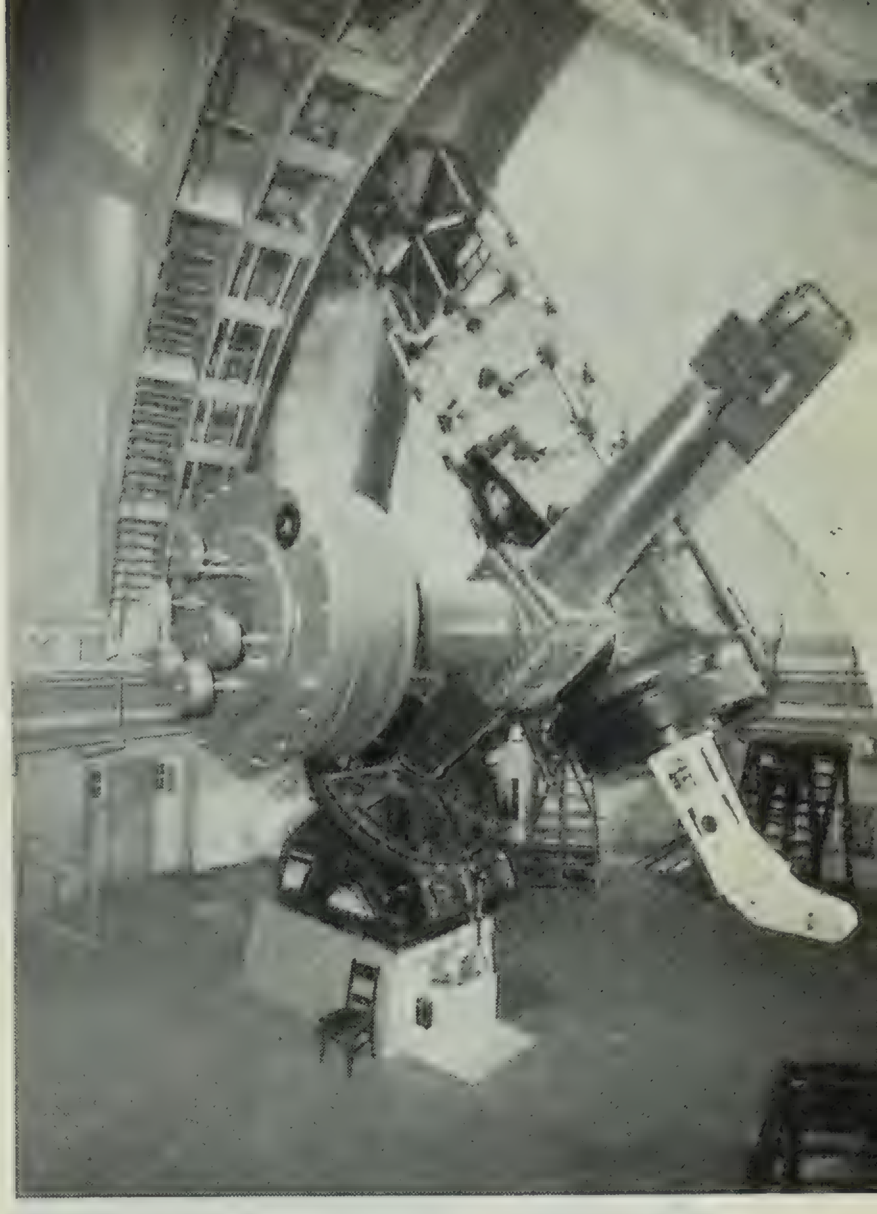
How can a scientist *prove* that one idea is true and another false? Let us examine an actual case, and find out.

Some 2200 years ago, there lived in Greece a great thinker and writer — Aristotle. He was one of the most learned men of all time, and he closely observed the world around him. One thing in particular aroused his curiosity. He noticed that when leaves, or feathers, or any other light objects fell through the air, they fell slowly, but that stones and other heavy objects seemed to fall very rapidly. From these observations, he concluded that the speed with which a body falls through the air depends upon its weight: the heavier it is, the faster it falls.

If Aristotle had lived in our day, he would have realized that he was taking too much for granted, and he would have tested his idea by experiment. But 2200 years ago, the method of testing ideas and finding facts by experiment was unknown. Many of the instruments that scientists use today had not been invented. Aristotle had no X-ray machine, for instance, and no telescope, microscope, or any kind of accurate measuring instrument. He simply observed the world about him and drew his own conclusions. But he was so wise that people accepted everything he said, without questioning it. And so, for hundreds of years, everyone believed that heavier bodies fall faster than lighter ones.

About 350 years ago, another great thinker, Galileo Galilei, questioned Aristotle's conclusion. He proceeded, by experiment, to test the truth of Aristotle's belief about the speed at which bodies fall.

He went to the Leaning Tower of Pisa, which stood in his home city, taking with him cannon balls of varying weights. From the top of the tower he dropped them, all at the same instant. All the cannon balls, light and heavy, struck the ground at the same time. Galileo tried the experiment again, with different objects. Time after time he made the test, and each time the objects he dropped fell at a uniform rate, no matter what they weighed. At last Galileo felt sure that all bodies fall at the same rate regardless of their weight and that Aristotle's belief was wrong. So firmly convinced was he, that he asked the teachers from the University of Pisa to come and watch his experiment. All the teachers still firmly believed that Aristotle's statement was true. They watched Galileo drop the various weights from the tower, and observed that they all struck the ground at the same time; but even in the face of such clear evidence, some of them were still unconvinced. As time went on, however, people came to accept Galileo's statement as a fact, because he had proved it by experiment.



The size of the seventy-four-inch telescope of the David Dunlap Observatory, Richmond Hill, Ontario, can be estimated by comparing it with the chair in the centre foreground. In this book, you will read about heavenly bodies discovered by scientists with the aid of modern instruments, such as this telescope.

As scholars watch from below, Galileo drops a ten-pound weight and a one-pound weight from the top of the Leaning Tower of Pisa to test, by experiment, Aristotle's belief that bodies of different weights fall at different speeds. (International Nickel Co. of Canada Ltd.)

Gradually other thoughtful men adopted Galileo's way of finding the truth. They began to question ideas, and to test them. They were able to prove the falsity of many foolish notions, and to build up true ideas about the world around them. Galileo is known as the Father of the Experimental Method. He approached problems in a scientific way, and solved them by scientific methods.

In this introductory section to *Science Activities,* you will learn more about the attitude that marks a true scientist, about the kind of problems that a scientist faces, and about his method of solving them.

A helicopter patrolling a forest area. Studying science will help you to answer such questions as: How does a helicopter fly? How can a helicopter be used to fight forest fires? (Ontario Department of Lands and Forests photo)

HOW TO USE THIS PART OF THE BOOK

The purpose of the introductory section of *Science Activities* is, as the title suggests, to help you to make a good beginning with your science work for the year. It is a very important part of the book, but it is not intended to be studied intensely as a unit.

Rather, it is to be regarded as a *key* to the rest of the book — a key that will open the door to a number of very important ideas and help you to understand and use the units that follow. Our era is often referred to as "the age of science." You already know something about scientists and their work. In the introduction, *scientific method and scientific attitudes* are outlined and explained. Understanding and applying them will bring you greater benefit and enjoyment from the world around you.

Be sure, therefore, to read this introductory section carefully. Discuss it with your classmates and begin *now* to make use of the ideas outlined. They will be referred to many times throughout the book.

In the meantime, move forward quickly to the first chapters. *Take advantage of the warm days of early fall to study, outdoors, mammals, birds, insects, and other living animals. Later, they will not be available.*

These pupils are taking advantage of fall days to study trees. They are making use of two methods of studying science. (1) They have been outdoors to make first-hand observations and have brought back several specimens to identify. (2) They are now reading to check and add to the knowledge that they gathered on their trip. (Bruce Pendlebury photo)

How does science affect your life?

Mr. Kennedy and his pupils were talking about science. "There are many reasons," he said, "why everyone should know something about science."

It was Sandra Martin who added, "I read that we are living in a time of new discoveries and inventions."

In the discussion that followed, the pupils discovered many ways in which science affects our lives.

Questions answered

"I like studying science," exclaimed Fred Blake, "because I find the answers to so many questions that have puzzled me. *Why* do stars twinkle? *What* is magnetism? *How* is water power changed to electricity? *Where* do birds go in winter?"

"Scientists have discovered and put into orderly arrangement a great and ever-increasing body of knowledge about the materials and forces

The pioneer Canadian woman made her own soap. Water, poured into a barrel of wood-ashes, soaked through, and trickled out from the bottom as lye. The lye, when boiled with fat in an iron kettle, produced soap for the family. Today, soap and detergents are manufactured commercially and sold in stores. (International Nickel Co. of Canada Ltd.)

in our surroundings," Mr. Kennedy explained. "This knowledge can be found in books, bulletins, films, and other similar materials. It is there for anyone who wishes to use it."

Interesting things to do

"To find the answers to many of our questions we don't have to go to books," said Gordon Pearson. "What I like about science is being able to find things out for myself by performing experiments and by making outdoor observations."

"Yes," said Mr. Kennedy, "the study of science usually results in an increasing thirst for knowledge and consequently in more reading, more experimenting, and more outdoor observations. As you become better informed in the field of science, you will want to know more and more."

Scientific method and attitudes

Janet Brown, who had been reading about scientists, explained. "Scientists have developed a method of solving problems and making new discoveries which is called the *scientific method.* If we work carefully, we shall learn and think more scientifically."

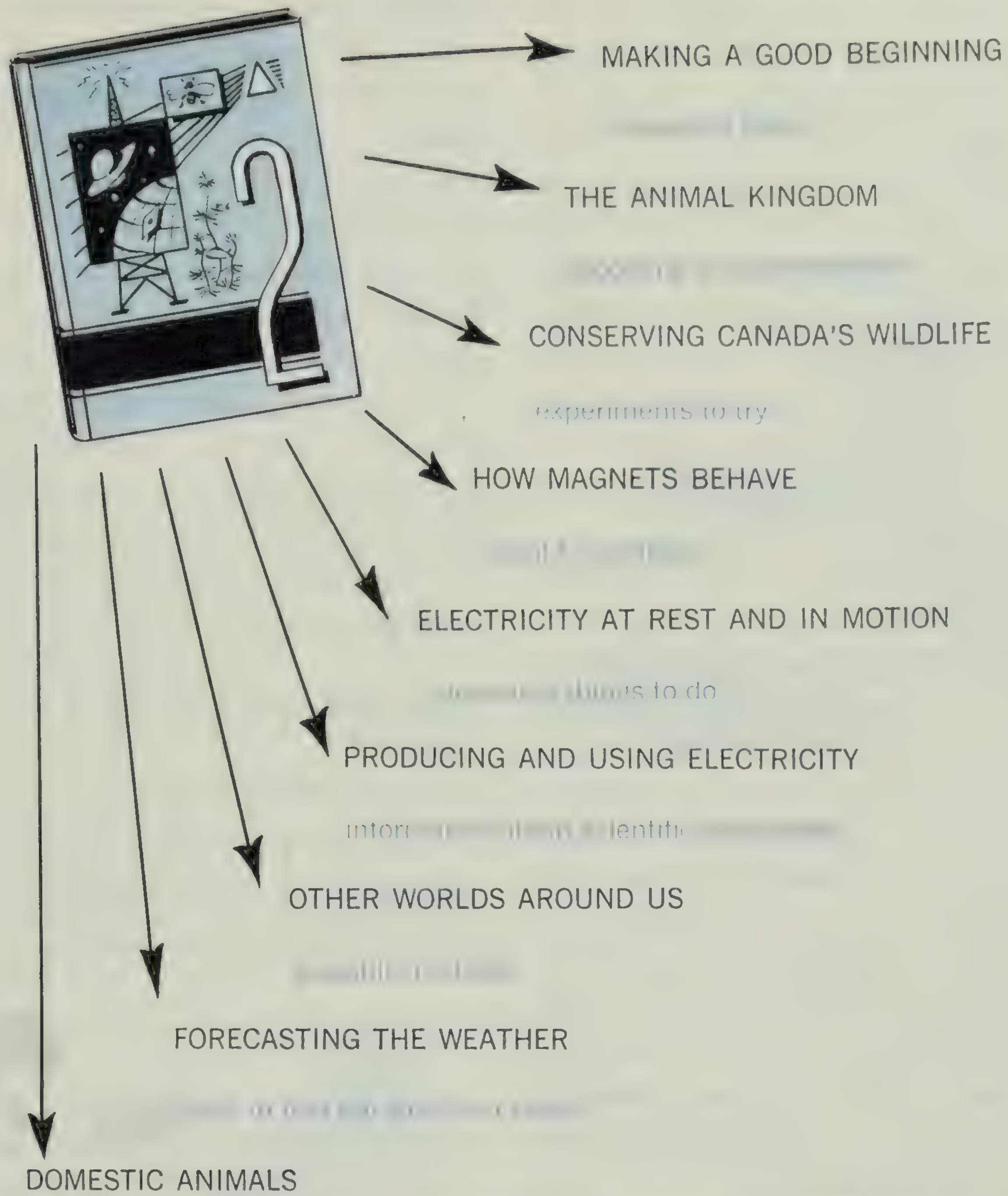
Before the discussion concluded, the pupils agreed that a knowledge of science enriches our lives in many ways. Understanding scientific truths enables us to live in the world without fear and superstition. Studying science increases our powers of observation and research, brings us the enjoyment of contact with the outdoors, engages us in interesting activities, and makes us appreciative of the many factors that contribute to our comfort and enjoyment.

How to use your science textbook

Your study of science should be an exciting adventure. How can you best use *Science Activities, Book Two* to make this adventure as interesting and profitable as possible?

1. In *Science Activities, Book Two,* you will discover some of the ways in which *science enables us to improve our ways of living and working with others in our social environment.* The various chapters tell the story of contributions that science has made in such areas of living as *food production, transportation, communication,* and *conservation.*

As you know, science has not only made it possible for us to build great highways, airplanes, and power plants, but it has also contributed much to our comfort, convenience, and safety at home and at work, and while travelling from place to place.



The illustration above tells you about the contents of *Science Activities, Book Two.* The black labels list the topics covered in the various chapters. The labels in color tell about other important features.

If you read the text thoughtfully and carry out a number of the activities suggested, you will greatly increase your understanding of the part science plays in our modern way of living.

The illustration above will give you some idea of the *topics discussed* and of the *experiments and other activities that are outlined.*

2. But science is more than knowledge. It is *a way of working and a way of thinking.* As you work through *Science Activities, Book Two,* you will have many opportunities to practise the *scientific method* and to develop *scientific attitudes.*

This method and these attitudes cannot be learned merely by reading about them. It would be useless to

try to memorize them. They can be learned only by using and practising them from day to day.

An important feature of this book is the abundance of suggestions regarding *things to do* and ways of doing them. Be sure, as you begin each new section, to carry out at least some of the activities suggested and to gather as much information as you can about each topic, before reading on in the book to the factual information presented.

3. TESTS. — Has it ever occurred to you that tests are *sign posts* along the way to tell you how far you have travelled in the study of science? Not only do tests provide you with an opportunity to show what you know, but they also help you to find out what you do not know. It is often very important to learn where there are gaps in your knowledge of a subject.

Here is an outline of what the tests in *Science Activities* will do for *you:*

(*a*) Some will tell you whether you have built up a *worthwhile body of science information.*

(*b*) Some tests will show you whether you really *understand important science ideas and terms.*

(*c*) Other tests will reveal whether you *can apply science information and ideas to new situations.*

(*d*) Some will check the extent to which you *are developing scientific attitudes* and *skill in using the scientific method.*

Mr. Kennedy suggested to his pupils that they assist him with the planning of the tests to be used at the end of each section of their science activities. "If we work together," he said, "we can plan a testing program that will do much more than show only what we have memorized." The pupils thought that it would be fun to help to prepare their own tests, and that in so doing they would also learn a great deal.

Be sure to make use of the many tests and activities outlined, to determine how well you are doing, where you may be making mistakes, and how you can improve as your science work proceeds.

What marks the attitude of a scientist?

> 1. *Curiosity is an important attitude of a scientist.*

We have seen that Aristotle was mistaken in his ideas about falling bodies. But though his conclusions were wrong, Aristotle possessed some of the attitudes of a scientist. He saw leaves falling from trees in the autumn and great stones falling from cliffs; and he thought he noticed a

difference in the way they fell. He wondered about it, and tried to decide wherein the difference lay.

Every scientist notices the way things happen, and wonders why they happen in that particular way. He tries to find an explanation for everything that seems to him unusual. Scientists are so curious that sometimes they are described as "living question marks."

Some people do not realize how many interesting things to do and think about are to be found near at hand. Your study of science will help you to discover many of these things.

> 2. *A scientist is not superstitious. He believes that for everything that happens there is a natural cause, and he seeks to discover it.*

Many people wonder why things happen the way they do, but often they do not try by scientific methods to discover the reason. Have you ever heard a schoolmate say that something pleasant happened to him because he had found a four-leaf clover, or because he kept a rabbit's foot or a horse-shoe; or that he had bad luck because he broke a mirror or walked under a ladder?

A football player wearing a sweater bearing the number thirteen broke his leg in a recent game. Do you think that this proves that thirteen is an "unlucky number"? If a scientist were asked this question, he would collect more evidence before answering it. After investigating all the games played in a season over the whole country, he probably would tell you that of all the players injured, as many were wearing each of the other numbers as were wearing the number thirteen.

Such explanations of "good luck" or "bad luck" as those we have mentioned are blindly accepted beliefs, or *superstitions.*

When the scientist observes an occurrence, he considers all the possible causes in order to decide which is the one true cause. He makes very careful observations, and, wherever possible, experiments to find the truth. Such were the scientific methods and attitudes employed by

the Italian naturalist Francesco Redi, who lived in the seventeenth century.

It is common knowledge that if fresh meat is left exposed for a few days in a warm place, small, white, wormlike maggots usually appear in it. Many years ago, people believed that these maggots grew from the meat; in other words, that living things could come from dead matter. Redi questioned this belief and set about to test it by experiment. He put a piece of meat into a bottle and covered the mouth of the bottle with a piece of cloth. He soon observed that flies gathered around the bottle and laid eggs on the cloth. Later, these eggs hatched into maggots, but Redi found no maggots in the meat. He repeated the experiment a number of times, always with the same result. He concluded, therefore, that maggots are the young of flies, and came from eggs, not from meat, which was dead matter.

A person with a scientific attitude refuses to accept a belief unless he knows it to be based upon facts.

> 3. *Open-mindedness is an important attitude of a scientist. He is willing to accept new ideas when he knows them to be true.*

A scientist never dismisses the ideas of other thoughtful people as worthless. He considers them carefully, and is willing to accept them if he finds that they are true.

Suppose, for example, that you have always believed that all hawks are harmful. You may even have supposed that it would be a good thing if these birds were to be shot and destroyed. One day, a friend tells you that your conclusion about hawks is not correct. Would you not be wrong if you simply refused to listen to him because you have always believed differently? Would it not be better to keep your mind open until you had given him an opportunity to support his statement with some facts?

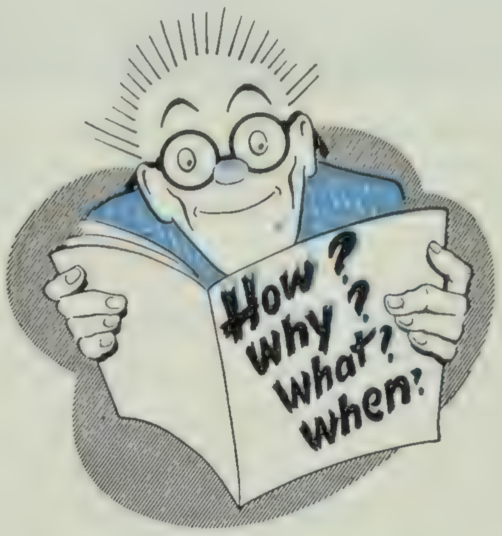
Actually it has been proved that most hawks are beneficial. Scientists have examined the contents of the stomachs of a great many hawks and have learned that most of the largest and commonest of them feed upon mice and gophers. The food of others consists chiefly of insects. Only a few hawks prey upon poultry or other birds.

A person with a scientific attitude (1) would listen to his friend and ask him upon what information he based his statement, and (2) would accept his statement as true after hearing the facts. Such a person would be *open-minded* — that is, willing to accept new ideas when they are supported by reliable information.

4. *A scientist does not jump to conclusions. Before forming an opinion on any question, he carefully considers all available information and then bases his decision on the facts.*

You will say, and quite rightly, that no one can take the time to check every statement, to satisfy himself as to its scientific truth. Life is too short. Some ideas we must accept, but we must also know when to question statements.

A statement made with a selfish object in view may often prove to be unsound. At a recent summer fair, a salesman was offering "snake oil" at the greatly-reduced price of fifty cents per bottle. He guaranteed that it would cure rheumatism, bronchitis, arthritis, stomach ulcers, boils, growing pains, corns, and a host of other ailments. Someone in the crowd challenged his statement. "What!" the salesman said. "You don't believe it? Read it for yourself, then. Here it is in *print* right on the bottle." When you know *why* the salesman stated that he had a guaranteed remedy for all the ailments that he mentioned, you realize that it would be unscientific to accept his statement as true.



The salesman tried to prove the truth of his statement by showing it in print. Do you believe everything you see in print? How much of what you read or hear on the radio or television should you believe? You should cultivate the habit of examining critically what you read or hear, because while much of it is true, some of it is not.

Very often we have to rely on the opinions of others, but before doing so, we should satisfy ourselves that those who express the opinions are qualified to arrive at correct conclusions. For instance, if a distinguished scientist predicts an eclipse, we accept his prediction; but if someone who knew no astronomy foretold an eclipse, we should be justified in paying no attention to him.

Before accepting a statement as a fact, a person with a scientific attitude considers the reason why the

This trained scientist is at work in a government laboratory, studying the problem of insect pests that destroy forests. (Department of Agriculture photo)

statement has been made, and satisfies himself regarding the authority behind the statement.

One day, James Duncan searched his desk in vain for his science textbook. He promptly reported to the teacher that the book had been stolen. No scientist would thus "jump to a conclusion," and neither should James have done so. There were several possible reasons for the disappearance of the book. Another pupil might have borrowed it, or James might have left it at home or in his locker, or he might have lost it on the road. James should have examined all these possibilities before coming to a conclusion, and particularly before charging theft.

We are all tempted at times to accept statements as true, simply because we want to. Do you sometimes find it easy to believe "gossip" about persons you dislike? This is a natural weakness against which we should all guard. We should never accept such statements unless they are supported by convincing proof. We should disregard our own feelings and base our conclusions only on fact.

A true scientist does not allow his likes and dislikes to affect his reasoning. He investigates very carefully and considers all the available information before forming an opinion on any question.

What is a science problem?

We all have problems to face; therefore it should not be hard for us to define a problem. What problems have you solved during the last few days? Probably you have been working at problems in arithmetic; this is a type of problem you have known for several years – one in which the particular facts that are given are used in finding the answer. Day after day you are solving problems in living, answering such questions as: At what hour should I get up in the morning? What should I wear? What books should I take to school? How can I earn some spending money? What game shall we play? In fact, every time you make a decision, you are solving the problem: "Which of the choices before me seems best?"

In science, as in arithmetic, problems are presented, but usually in science the facts to be used in solving the problems must be gathered by observation. In science, as in our everyday life, decisions must be made and difficulties overcome.

A science problem, then, is a question that must be answered, or *a difficulty that must be overcome in the field of science.*

To make this definition quite clear, let us look at some examples of

science problems that have already been solved. You will notice that they touch many different fields of living.

1. Let us first examine some of the problems that scientists have solved in the production of crops and livestock to feed the people of the world. New disease-resistant, heavier yielding varieties of crops and breeds of better fleshed livestock of higher quality have been produced. From time to time, when fruit trees or grain crops have been attacked by new insect pests, scientists have found means of controlling them. When the poultry or cattle of a locality have become sick and have died in unusual numbers, scientists have found the cause of death, and the remedy for the disease.

2. In the field of health, many problems have been solved by scientists. The causes of many diseases have been discovered, and new and better methods of treating them have been developed. In many cases, experiments have revealed ways of preventing the spread of diseases. It has been discovered that smallpox, for example, may be prevented by vaccination, and diphtheria by antitoxin.

3. Two hundred years ago, travel was confined to land and sea, and was very slow. Even as recently as eighty years ago, when Jules Verne wrote *Around the World in Eighty Days,* this was a highly imaginative feat. But many years of experimenting on the part of scientists and inventors have transformed George Stephenson's *Rocket* into the powerful locomotive of today, the little sailing vessel into a modern fast-travelling steamship and motor boat, and the machines in which man made his early attempts at flying into the present-day giant airplane, capable of travelling well over 500 miles per hour. Around the world in *eighty hours* is now an accomplished fact.

The new plastic materials produced by scientists can be used in many different ways. Left: The body of this truck is made of plastic strengthened with glass fibres. It will not dent or rust, and is easily repaired. Although light, it is stronger than an aluminum or steel body of the same weight. Right: A comb made of the plastic zytel. (Left, Naugatuck Chemicals photo; right, Du Pont Company of Canada Limited photo)

4. As airplanes were equipped with heavier engines, more instruments, and larger fuel loads, mounting weight became a serious problem Scientists sought lighter materials to substitute for the heavy metals. They found them in *plastics*. Today, plastics which are light-weight yet very strong are used in place of glass and other materials in the manufacture not only of planes but also of a great number of other articles. Plastics are of many different kinds and are made chiefly from such common materials as cotton, sour milk, coal, tar, air, limestone, and water.

5. The moment a material becomes scarce or expensive, scientists seek to produce a substitute. Artificial silk or *rayon,* made from wood pulp, replaced the much more expensive real silk for many purposes. Now, *nylon,* the raw materials for which are coal, air, and water, has become an even more valuable substitute for silk. Other new materials, such as *orlon* and *dacron,* are being developed from time to time.

This girl's clothing is protected by orlon coveralls as she washes her car with a brush made of nylon bristles. (Du Pont Company of Canada Limited photo)

6. Weather forecasts are becoming increasingly important to more and more people. As scientists learn more about the causes of weather conditions, they are able to make accurate forecasts for longer and longer periods.

7. Every new invention brings in its wake a host of new problems for the scientist. The invention of the airplane, for example, brought with it the problem of constructing runways, airports, and sensitive instruments of many kinds. With the demand for greater and greater speed came problems of new designs, new fuels, more powerful engines, lighter and stronger materials for construction, and so on. Every year new problems arise, and every year more trained scientists are needed to solve them.

What is the scientific method of solving problems?

A class of boys and girls decided to hold a party on a certain date. At once they were faced with the problem of deciding what would be the most popular type of party to have. They recalled previous successful parties. One pupil proposed a theatre

party; another, roller-skating; and others a wiener roast, a house party, and a scavenger hunt. After some discussion, the theatre party was discarded because no suitable show was billed for the date. Roller skating proved unacceptable because only a few of the pupils knew how to skate. A house party did not appeal, because the weather promised to be fine, and the majority of the pupils preferred to be out-of-doors. The problem was thus reduced to a choice between a wiener roast and a scavenger hunt, and was finally settled by a vote in favor of the wiener roast. The wisdom of the decision was put to the test by holding the party according to plan. Since the class voted the wiener roast as the "best yet," it may be concluded that the correct answer to the problem was found. This conclusion was verified by holding equally successful wiener roasts on several other occasions.

In solving problems by the scientific method, six steps are necessary. All six of these steps were taken in solving the problem of the class party.

The ***first step*** is to *have clearly in mind what the problem is.* The class wondered what kind of party to have.

Boy Scouts examine a nylon tent secured with nylon ropes. In fibre form, nylon is used to manufacture many things such as fabrics for clothing, upholstery, and tires. In plastic form, it is used to make gears, tumblers, combs, and many other articles. (Du Pont Company of Canada Limited photo)

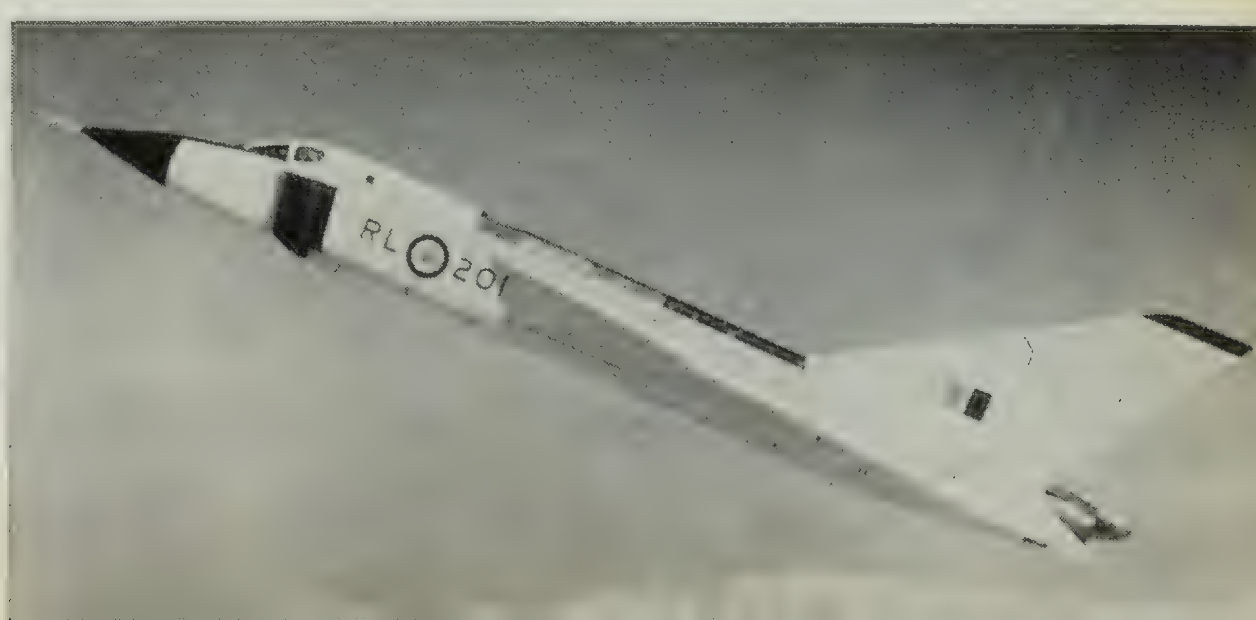
The ***second step*** is to *recall past experiences.* The students recalled other parties that they had enjoyed.

The ***third step*** is to *suggest possible solutions, and on the basis of all the facts to choose the most likely one.* From five kinds of parties that were suggested, the pupils selected the wiener roast.

The ***fourth step*** is to *make a test, by experiment if possible, to discover whether the chosen solution works.* This the pupils did by holding the party according to plan.

The ***fifth step*** is to *draw a conclusion.* The pupils concluded that a wiener roast is a satisfactory party.

The Avro "Arrow" during test flights. This Canadian plane exceeds a speed of 1000 miles per hour. (Avro Aircraft Limited photo)



The ***sixth step*** is to *repeat the test in order to check the conclusion.* No scientist is ever satisfied with one test; he repeats the test again and again until he is sure that the results are correct. The pupils held wiener roasts on other occasions, and so confirmed their conclusion regarding the success of this type of party.

Thus we see, that, however simple the problem, it can best be solved by the scientific method. We should therefore develop the habit of using this method to solve every problem we have to face.

SOMETHING TO DO

Using the six steps of the scientific method, outline how *one* of the following problems might be solved:

In well-equipped laboratories all over the world, scientists test their ideas by experiment. (Merck and Company Incorporated photo)

1. *Which television set shall I buy?* Consider such details as: various makes, distance of your home from the broadcasting station, the money you have to spend, etc.

2. *Which variety of potatoes shall I grow?* Consider the purpose (early or late), varieties now grown in your locality, the possibility of disease, etc.

3. *What shall I wear today?* Consider such details as the clothes you have available, the weather, your activities during the school day, etc.

4. A strange bird flies into your school yard. Explain fully how you could use the scientific method in identifying it.

5. A boy went to a hardware store to buy a vacuum bottle. The storekeeper showed him two bottles which looked much alike but one of which was nearly double the price of the other. Tell how the boy could use the scientific method in deciding which vacuum bottle to buy. Be sure to include an experiment as part of the method.

What is an experiment?

As we have already observed, a scientist tests his ideas by experiment (step 4 of the scientific method). To discover what an experiment is, let us examine one that was performed by Betty Smith.

Betty wanted a dress made from some material that she had admired in a store. Before purchasing the material, however, she wanted to be sure that the colors would not fade when the dress was washed. With this end in view, she secured a sample of the material to take home for testing. Cutting the sample in two, she

set one piece aside to be kept for comparison, that is, as a *control:* the other she washed thoroughly in soap and water. A close comparison of the two pieces showed Betty that the piece she had washed lost some of its original brightness. Concluding, therefore, that the cloth was not "color-fast," she did not buy it.

Let us see if Betty carried out her experiment correctly – if she took the six steps that should be taken in performing an experiment. You may remember the steps by these headings:

1. ***Problem*** – *what you want to know.* Betty decided what her problem was: she wanted to know whether the material was color-fast.

2. ***Apparatus and Material*** – *what you use in performing the experiment.* Betty assembled all the materials that were needed – dress-goods, soap, and water.

3. ***Method*** – *what you do.* (1) Betty divided the sample of cloth and laid one piece aside. (2) She washed the other piece in soap and water. (3) She compared the washed piece with the control (the unwashed sample).

4. ***Observation*** – *what you see.* Betty observed that the washed sample was less brightly colored than the control.

5. ***Conclusion*** – *what you learn.* Betty learned that the dress material was not color-fast.

6. ***Application*** – *what use you make of your discovery.* Betty decided not to purchase the material, and thus avoided loss and disappointment.

When you are recording experiments in your science note-book, arrange your records under the six headings mentioned on the left.

THE SCIENTIFIC METHOD AND AN EXPERIMENT

You must not think that the scientific method and an experiment are the same thing. What is the difference?

Think carefully about these two statements:

1. The *scientific method* is more than an experiment.

2. An *experiment* is just *one* of the six steps in the scientific method.

Which step of the scientific method involves an experiment?

What has the scientific method achieved?

It would be impossible to state in full all that the scientific method has achieved. But it is well to think of some of science's miracles of achievement, miracles that we too often take for granted. Picture the world of the future that science is making possible. As you read on, think what your life would be like if men had never become scientists.

Most of the ***comforts*** with which we are surrounded have been provided by the work of scientists. *Glass windows* admit light to homes and offices during the day, and *electric lights,* by giving illumination at night,

The home of the cave man, one of thirty-four panels by G. A. Reid, R.C.A., in the Royal Ontario Museum. Compare this home with the one in which you live. What comforts and conveniences have you that early man did not possess?

provide comfort in reading, sewing, and other activities requiring good light. Many modern buildings are now insulated with *rock wool,* which, by shutting out the heat in summer and keeping it inside in winter, keeps the buildings at a comfortable temperature the year round. Heating plants with *air-conditioning* provide warm, clean, moist air, free from dust and germs. Trains, airplanes, automobiles, and ocean liners have every modern form of luxury for comfort and enjoyment. All these improvements are the result of scientific discoveries.

It is frequently said that the world is becoming smaller. What this statement really means is that improved means of ***communication and travel*** make it possible to reach safely almost any part of the world in a comparatively short time. Scientists are investigating the possibility of travelling to the moon. New fuels, engines, and materials, as well as improved methods of enabling men to live out in space beyond the air, make even longer journeys into space seem within the bounds of possibility.

Jet-propelled airplanes can already (1959) fly as fast as the speed of sound, and new planes are being designed that will travel 1500 miles per hour (25 miles per minute), or about twice the speed of sound. Many years of scientific investigations were required to produce machines capable of such speeds. (A. V. Roe Canada Limited photo)

Scientists have also contributed to the development of many inventions that are of great ***convenience.*** The *telephone, washing machine, refrigerator, sewing machine, electric stove,* and *vacuum cleaner* are in use in many modern homes. Can you think of other conveniences in and about your home that we owe to the research and discoveries of scientists?

In the production of ***safety devices,*** science has played an important part. The *Davy's safety lamp,* for example, lessens the danger of explosions in mines. *Shatter-proof glass* in windshields and windows reduces the number of injuries in automobile accidents. When visibility is poor, *radio-beams* keep pilots on their course. *Automatic sprinklers* instantaneously turn streams of water upon fires. When short circuits occur, *fuse plugs* disconnect electric circuits, thus preventing many a fire. *Weather instruments* make it possible to forecast the weather and so to warn fishermen, airplane pilots, ships' captains, and others of approaching storms.

Our ***health*** also has greatly benefited from the discoveries of science. Scientists have experimented to produce *balanced diets,* containing all the most nourishing foods in the right proportions. Scientific research has shown that *special food preparations,* such as cod liver oil, can be used to supply essential vitamins, which we may otherwise lack, especially during the winter months. *Water and food supplies* are scientifically tested and steps are taken to ensure their purity.

X-ray photographs, like this one of a broken leg, enable doctors to diagnose correctly injuries and diseases within our bodies, and thus more accurately to prescribe remedial treatment.

Radium and X-ray, discovered by scientists, are used in the treatment of cancer and other diseases. In many cases, also, X-ray pictures help doctors to find the causes of illness. Scientists

A scientist uses an electron microscope to study forestry problems. The electron microscope, which magnifies up to 30,000 times, has enabled scientists to discover many new facts. (Ontario Department of Lands and Forests photo)

have developed methods not only of treating diseases but also of preventing them from spreading. Protection from such diseases as diphtheria, typhoid fever, and smallpox can now be provided by *inoculation*. One of the comparatively recent discoveries — the *electron microscope*, which magnifies up to 30,000 times (fifteen times as much as the ordinary microscope) — has enabled scientists to learn many new things about disease-producing bacteria. The electron microscope holds out hope for further conquest of disease. The new *cobalt unit* has made possible the use of atomic energy to treat certain diseases.

A little thought will enable you to make your own list of ways in which science has contributed to your ***enjoyment*** of life. Think, for instance of the *printing press*, the *motion picture*, the *radio*, and *television*. How have they helped to make your life more pleasant?

How to increase your knowledge of science

The pupils in Mr. Kennedy's class were planning their study of the sun and the stars. They had become interested in several problems. Now they were deciding how to solve them.

1. "There are several good books about stars in the library," said Walter Emery. "I think we should do a lot of reading."

2. "Yes," exclaimed Mark Waltman, "I think we should. But, we'll never learn to know some of the stars when we see them at night unless we find a way to go outdoors to study them first-hand."

"You are right, Mark," said Mr. Kennedy. "Nothing can take the place of seeing things for ourselves. Has anyone a suggestion about how we could arrange to make a first-hand study of the stars?"

3. "Mr. Edwards knows about stars," suggested Mary Novack. "Perhaps he would come to school some night to show us a few of them."

"That's an excellent idea," replied Mr. Kennedy. "If the class would like to accept Mary's suggestion, perhaps she would see Mr. Edwards and try to arrange with him to come."

Music adds much to our enjoyment of life, and scientific discoveries are used in the construction of all musical instruments. The clarinet and saxophone players above are members of the wind section of a junior high school band. (National Film Board photo)

You will observe that Mr. Kennedy's pupils knew how to make their science activities interesting and were including in their plans several good methods of studying science.

1. ***Reading*** – which is excellent, but not in itself enough.

2. ***First-hand observations*** – nothing can take the place of first-hand experience in science. First-hand observations should include the following activities:

(*a*) *seeing things for yourself:* trips to farms, fields, woods, gardens, museums, creameries, and many other places; carefully observing things that you see on the way to and from school.

(*b*) *trying things out for yourself:* experimenting, making and using science apparatus.

3. ***Asking people who know*** – this, too, is an excellent way of securing reliable science information.

You will realize that to solve many science problems, it will be necessary to use more than one method at a time. If you look back over the plans that were being made by Mr. Kennedy's class in connection with their study of stars, you will see that they intended (1) to read about stars in several books, (2) to go outdoors to study stars, and (3) to ask Mr. Edwards to help them.

Looking forward

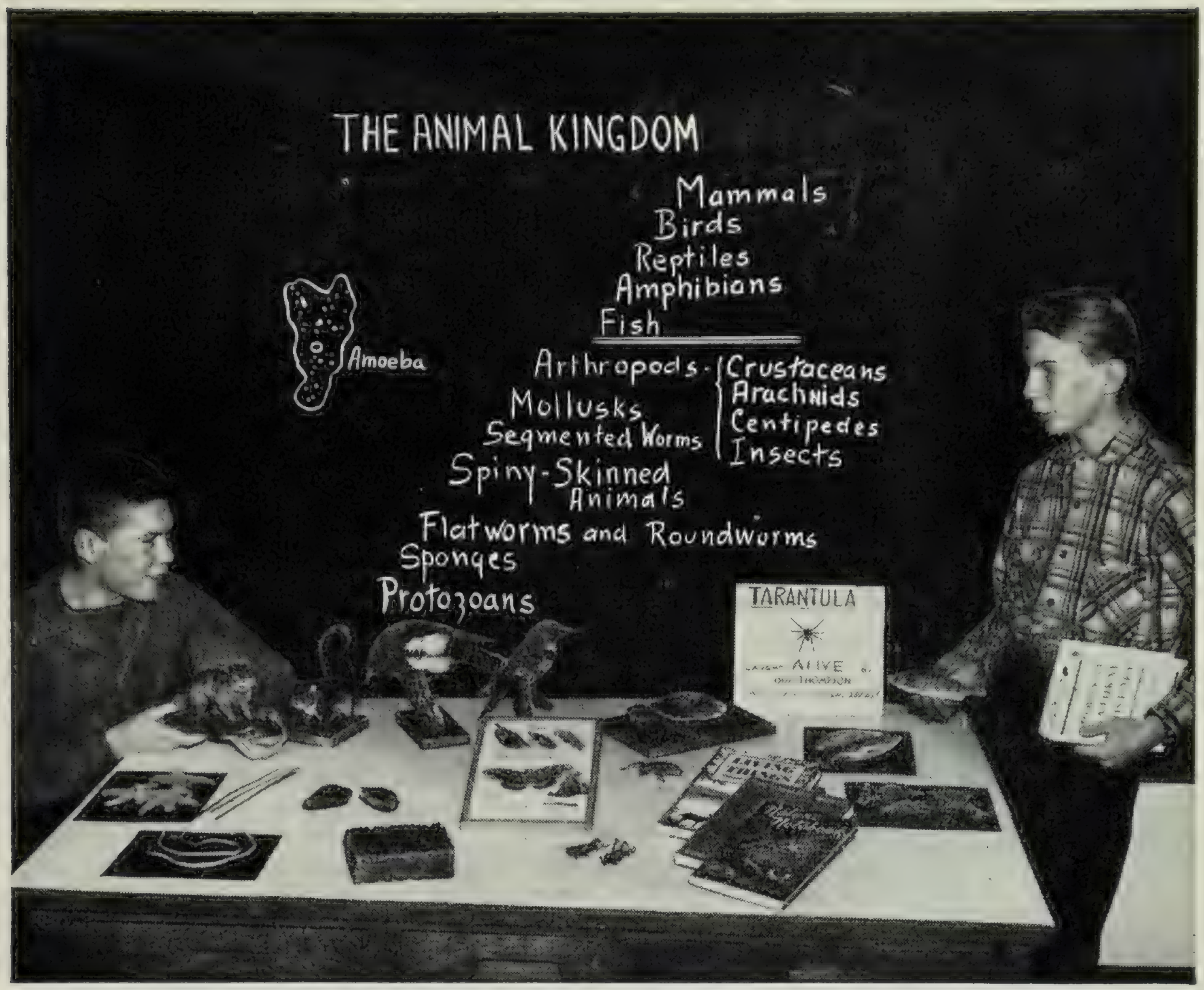
A very important thing to remember is that, while science has solved many problems, there are still a great many to be solved in the future – problems related to disease,

These two boys, who are interested in airplanes, are using two methods of finding out about them: (1) They are making first-hand observations at an airport; (2) They are asking questions of an officer who knows about planes and can give them much information. (Bruce Pendlebury photo)

The interior of a modern passenger plane. Science has done much to make this form of travel safe and comfortable. (Trans-Canada Air Lines photo)

food production, communication, transportation, and conservation. As you study science now, you should try to learn what some of these problems are. Having a knowledge of such problems will increase the appreciation and thrill of excitement that you will experience in the years to come when you read about scientists' success in finding solutions to many of these problems. It is possible, too, that *you* will make an important contribution to scientific discovery.

Although not all of us will become recognized as scientists, all of us need to know something about *science* and the *scientific method* in order to fit into modern life. The following chapters of this book will tell you the story of many more scientific discoveries and will suggest experiments that you may try for yourself, as well as outline other activities in which you will have opportunities to practise the scientific method and to develop scientific attitudes.



The study of the orderly progression of members of the animal kingdom, from simple one-celled creatures to the most highly developed of animals, man himself, is one of the most interesting branches of science.

CHAPTER 1

CHAPTER 1

THE GREAT ANIMAL KINGDOM

Fish, insects, oysters, and sponges are animals. How many other kinds of animals can you name? How do animals differ from plants? How are plants and animals alike? The dog, cat, deer, and man are among the animals classed as mammals. How do mammals differ from other animals? The study of the ways in which animals are fitted to live in their surroundings has occupied the attention of many people. What special adaptations are to be noted among the animals in your immediate locality?

DOES IT SURPRISE YOU that birds, fish, frogs, turtles, and snakes, and even grasshoppers, spiders, and earthworms are animals? Often we incorrectly use the word *animal* to refer only to four-legged animals such as rabbits, dogs, horses, and cattle. The scientist regards all living things as either plants or animals. Obviously birds, fish, and insects are not plants; therefore they must be animals. Scientists have already studied over 800,000 different kinds of animals; more kinds are added to the list each year. By seeing how scientists classify (put together in groups) different animals which are similar in certain ways, you will understand much more about the many interesting creatures that form the great animal kingdom.

COMPARING PLANTS AND ANIMALS

We have seen that there are two great groups of living things — plants and animals. All living things are members either of the great plant kingdom or of the great animal kingdom. Plants and animals are alike in some respects; but they are quite different in other ways.

How are all living things alike?

If you make the observations suggested in the "Something to Do" section that follows, you will become aware of the many similarities between plants and animals.

SOMETHING TO DO

Carefully observe some of the plants and animals around you. Try to recall all that you know about them. How are they alike?

1. Respiration. Do plants require air? Do they take in oxygen and give out carbon dioxide? How do animals breathe?
2. Food. Have you recalled that green plants make their own food and use it for growth, repairs, and other essential processes? Think about the activities in which animals engage to procure their food. What is the source of their food?
3. Growth. Consider the size of young plants that you have grown at home or at school. How big are kittens, puppies, chicks, calves, colts, and fawns? What change takes place in the size of these young plants and baby animals as they become older?
4. Production of new plants and animals. Have you recalled that plants reproduce either through seeds or by spores? In what form do cats, cows, and hens produce their young?
5. Movement. Notice how plants and animals move their individual parts and how animals move from place to place. Observe plants in a window. Turn one around and leave it in its new position for a few days. What happens?

Respiration.—Both plants and animals carry on respiration, or use oxygen to burn food in their cells. Both groups also give out carbon dioxide. Plants have tiny openings in their leaves and stems through which oxygen passes in and carbon dioxide passes out. Some animals breathe by means of lungs. Others carry on respiration through their skins. Many water animals have gills.

Food. — Both plants and animals require food. Green plants, that is, those with chlorophyll, manufacture their own food. Plants without chlorophyll secure their food from other plants or animals upon which they live as parasites. Animals, too, require food for energy, warmth, growth, and repair. Some feed upon plants; others eat other animals. Many animals have mouths, but the *amoeba*, a one-celled animal, simply wraps its whole body around its food. Both plants and animals must have water.

Growth. — You will have observed that plants and animals grow larger as they grow older until finally they become fully grown. Growth in some cases is quite rapid. In other cases it is very slow. Some animals change very greatly in form as they grow (tadpole to frog, caterpillar to butterfly). Growth in both plants and animals occurs when cells divide to form more cells of a similar kind.

Reproduction. — All living things reproduce, that is, produce more of the same kind. Flowering plants, as you know, produce seeds which are really tiny new plants with a supply of food. Flowerless plants, such as ferns and toadstools, reproduce by spores. What other means do you

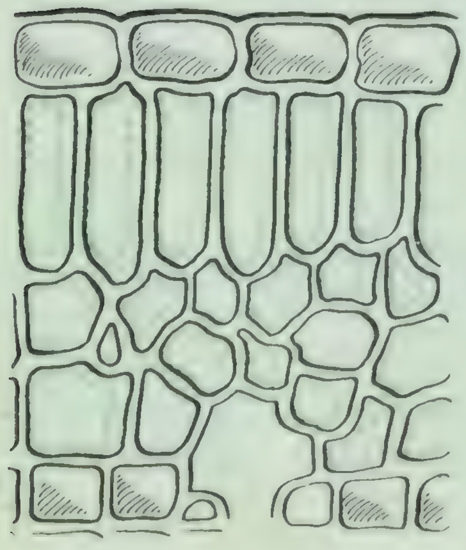
know by which some plants reproduce? Many animals give birth to living young. Many lay eggs from which young animals later hatch.

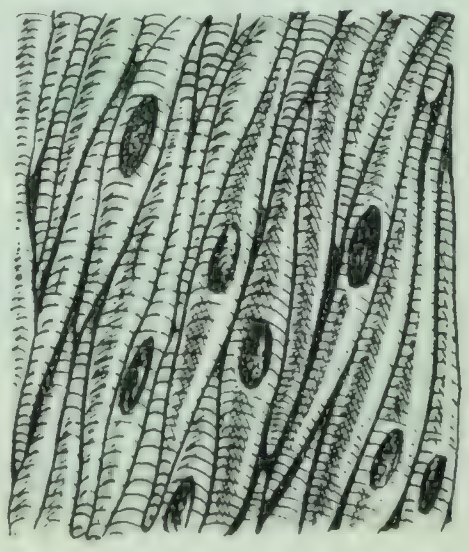
Movement. — Plants, as you know, do not move from place to place, but they do move under certain conditions. Plants in a window turn toward the light. The flowers of some plants, for example, morning glories and nicotine, close during bright sunlight and open on dull days or at night. All animals are capable of movement. Some move from place to place. Others, such as oysters and sponges, move parts of their bodies only.

Structure. — One other important manner in which all living things are alike is in the structure of their bodies. The bodies of both plants and animals are made up of tiny compartments, or *cells*. Most of these cells are so small that we must use a microscope to see them. Some plants and animals are made up of one cell only. The one cell does all the work necessary to keep the plant or animal alive. Your own body is made up of billions of cells. The cells of many animals are grouped to form the various parts of their bodies and to perform special kinds of work. Some cells form a stomach to digest food. Other cells make a heart to pump blood, which, in turn, contains white and red blood cells. Still other cells form muscles to produce movement. What other cellular tissues can you name and describe? In the case of plants, the leaves, roots, and stems are composed of groups of cells each with its special work to do in the manufacture and transportation of food and the other life processes of the plants.

The cells in living plants and animals are alive. They perform essential work and divide into new cells. This process results in the growth of the plant or animal. In the cell is a substance called *protoplasm*. Protoplasm is the substance that gives life to all living things.

Sensitivity to Surroundings. — Plants and animals are sensitive to their surroundings. The sunflower turns its face to keep it always toward





The bodies of both plants and animals are made up of cells. Left, the cells in a cross-section of a leaf as seen under a microscope. Right, the cells in a muscle are long, slender, and pointed. The cells in bones, nerves, blood, and other body parts are each different in shape. Cells in plants, too, are different, depending on the work they do.

Animals (and plants) respond to messages from their surroundings. These puppies appear to be both looking and listening. (National Film Board photo)

the sun. Certain plants close up when they are touched. These illustrations suggest another way in which plants and animals are alike — they react or respond to certain kinds of messages that come to them from their surroundings. When you call or whistle for your dog, he probably comes to you. Some animals follow their prey by sight, scent, and sound.

The ability to receive different kinds of messages that come to them from their surroundings and to respond to them is very important in the lives of plants and animals. It enables animals, for example, to escape from their enemies, find food, follow trails, and keep together in flocks or herds. In what ways do *you* receive and respond to messages from your surroundings?

How are plants and animals different?

You have learned that plants and animals are alike in a number of respects. In what ways are they different? One difference is that plants are unable to travel from place to place. Many animals travel long distances from one location to another. Another difference, and an important one, is the ability of green plants to manufacture food. Plants containing

chlorophyll can use energy from sunlight to combine carbon dioxide from the air with water from the soil to manufacture sugar. Not even man, among the animals, has learned how thus to produce food. In fact all animals, whether they are plant or flesh eaters, depend upon plants for the food they require. Explain how flesh-eating animals depend upon plants.

How are animals adapted to live in their surroundings?

There are many kinds of animals. They live in a wide variety of environments: on land, in soil, in the air, on other animals and on plants, in fresh water and in the ocean. Each kind of animal must be able to live successfully in its environment. Fish swim and secure oxygen from the water by means of gills. Earthworms eat their way through the soil and breathe through their moist skins. Grasshoppers can fly, and, like many other insects, they carry on respiration through tiny holes along the sides of their bodies.

It would take you a long time to become acquainted with all the adaptations of animals. A number are discussed later in this chapter. However, you can learn a great deal for yourself by carefully observing the animals that you see around you.

SOMETHING TO DO

Observe the animals in your locality to learn how some of them are adapted or fitted to live in their environment. Some animals that you can study are: pets and other domesticated animals; animals in fields and woods, in a zoo, or in an aquarium; insects on land and in water; birds that live on the ground, among the trees, or on the water; toads and frogs, earthworms, snakes, turtles, fish, and many others.

Organize your observations for a report to your class. Make sketches.

> As you study the following sections in this chapter, keep the problem of adaptation constantly in mind. Learn not only about classes or kinds of animals, but also how each is fitted to live in its environment.

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. To what two great kingdoms or groups do all living things belong?
2. List and briefly explain seven ways in which all living things are alike.
3. Discuss the fact that all living things are composed of one or more cells. What is the difference between the work performed by the single cell of a one-celled animal and that performed by a cell in the body of one of the higher animals?
4. In what ways do plants and animals differ?

5. Explain how animals respond to messages that they receive from their environment. How are the messages received? Give specific examples of how animals react or respond.

6. Each kind of animal must be adapted to live in its surroundings. Explain briefly, with examples, what this statement means.

INVERTEBRATES — ANIMALS WITHOUT BACKBONES

Scientists classify living things according to structure. What are the most important differences in the structure of various kinds of animals?

SOMETHING TO DO

Study the drawing of various animals on page 30. Separate them into two groups. What is the chief difference between the two groups?

The first step a scientist takes in classifying an animal that he does not know is to find out if it has a backbone. All animals with backbones are placed in a group called *vertebrates.* (A *vertebra* is the name given to each bone in a backbone.) Animals that have no backbones are called *invertebrates.*

As we study animal groups, we shall start with the microscopic one-celled animals in which the one cell performs all the work required to keep each animal alive. Our study will conclude with the highest group of animals in which the various parts of the body are highly specialized, each with its own special work to do. In between these two groups are many animals ranging from those with very simple forms to those with very complex body structures.

As our study proceeds, carefully observe how the bodies of each group of animals are slightly more complex than the bodies of the group studied immediately before them.

You may be surprised to learn that about 95 per cent of all the kinds of animals in the world are invertebrates. The invertebrates are divided into several groups.

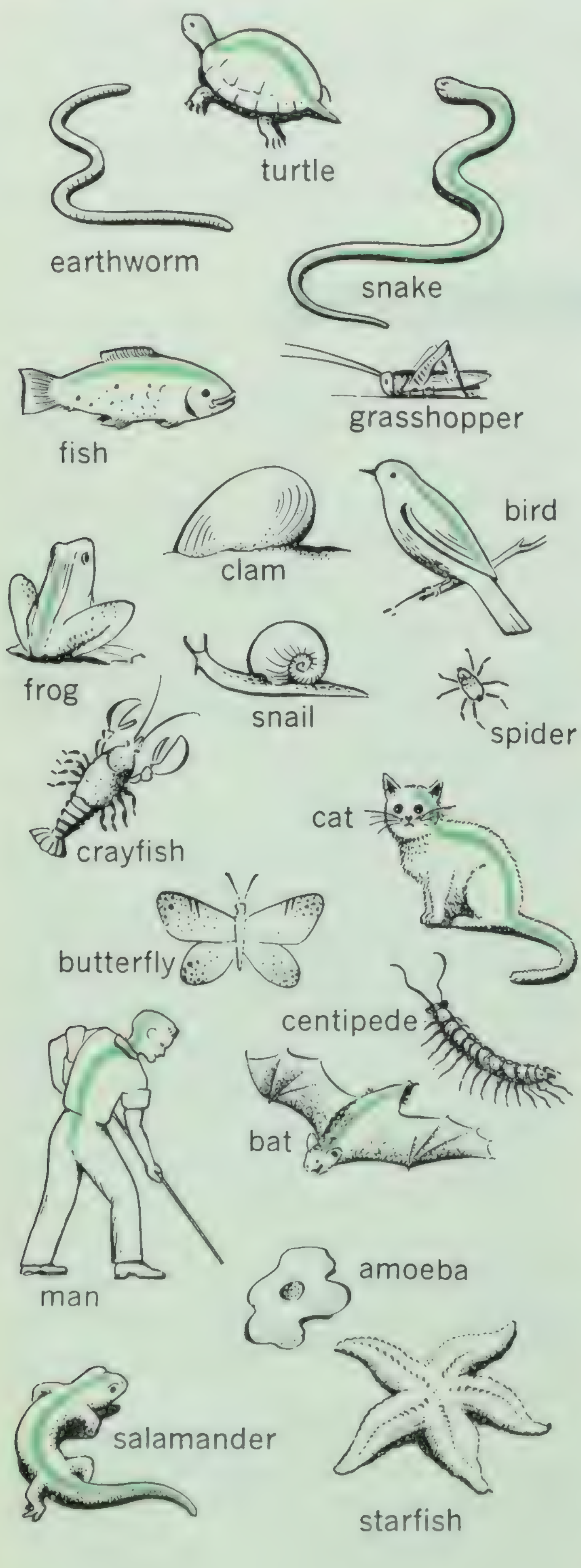
SOMETHING TO DO

1. Go on a hike to a pond or an open field, where, if you observe carefully, you should be able to study and collect many invertebrates. Watch for insects, spiders, snails, clams, and crayfish. Under rocks and logs you may find earthworms and centipedes, or "hundred-legged worms." None of these animals has a backbone.

2. Bring to class, if available, specimens of the following animals: sponges, snails, clams, oysters (or the shells of these animals), earthworms, starfish skeletons, spiders, insects, millipedes, centipedes, crayfish, and other invertebrates.

As you read further in this chapter you will find more information that will help you to see many of these animals in their natural environment.

Note.—If some of your animals are alive, be sure to keep them under conditions closely resembling their natural



Study this drawing carefully. Into what two groups can these animals be divided? Which ones are vertebrates?

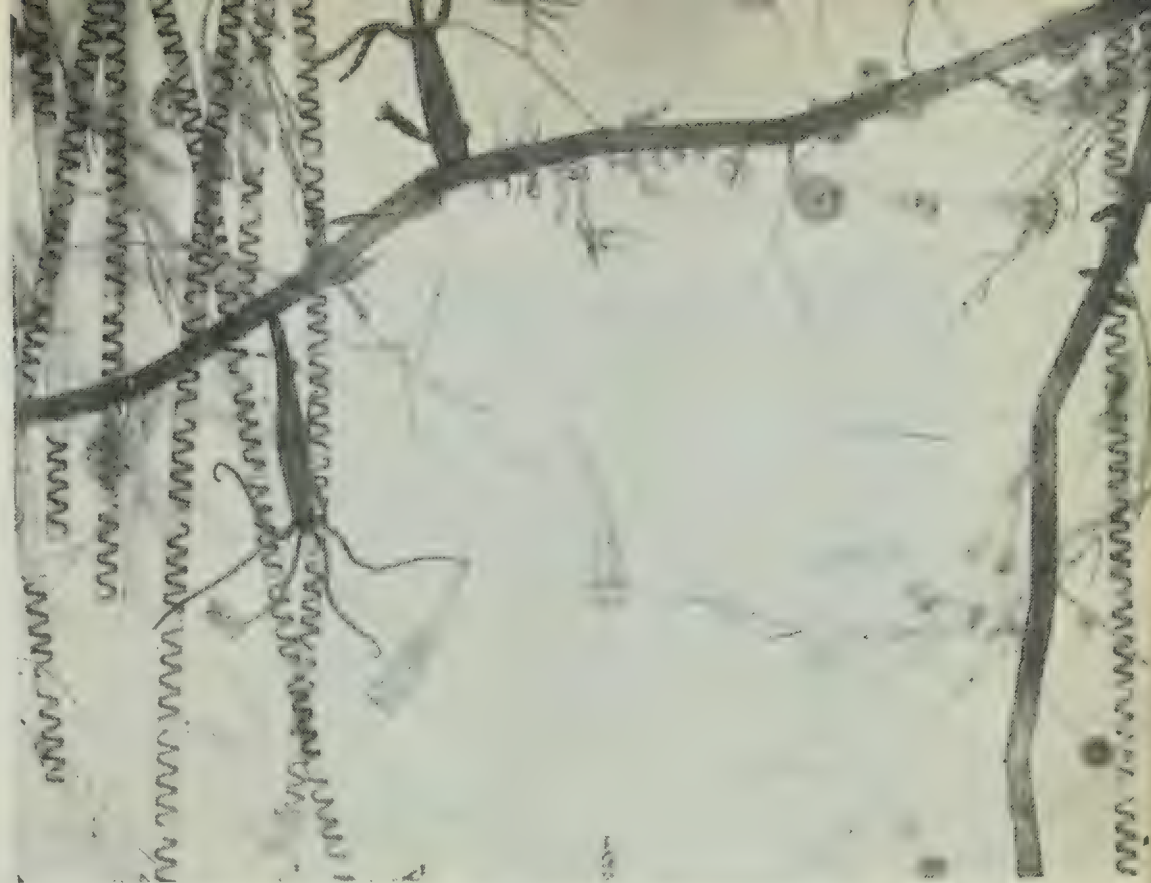
surroundings and to feed and otherwise take good care of them. Later release them.

3. For the purpose of observing one-celled animals, prepare a hay and water infusion. Fill a quart or pint jar about ¾ full of water. Add a few bits of hay or dried grass. Allow the mixture to stand at room temperature for several days. Just below the surface of the water you should be able to see grey, moving clouds consisting of thousands of one-celled animals. By means of a microscope (borrowed if necessary), examine a drop from near the surface of the water. Protozoans, or one-celled animals, should be easily seen.

Protozoans — the smallest and simplest animals

It may be a new idea to you that there are animals so small that they can be seen only with the aid of a microscope. As a matter of fact there are about 15,000 kinds. There may be hundreds, and even thousands, in a drop of water. A few kinds are large enough to be barely visible to the naked eye.

These tiny animals are called *protozoans*. Each protozoan is composed of one cell only. Protozoans feed on tiny plants and animals in the water and are very numerous. They are found in many places, such as ponds, lakes, and streams. Stagnant water, in particular, is full of them. Protozoans reproduce by simply dividing into two. Under favorable conditions this process can take place rapidly. A few protozoans can become very many in a short time.



The illustration shows a drop of pond water very greatly magnified. To find the names of several of the protozoans that you can see, refer to the illustration below. Several other kinds can also be seen. Microscopic plants (the thread-like strands with spiral bands, and others) are also visible in the water. (Bausch and Lomb Optical Company photo)

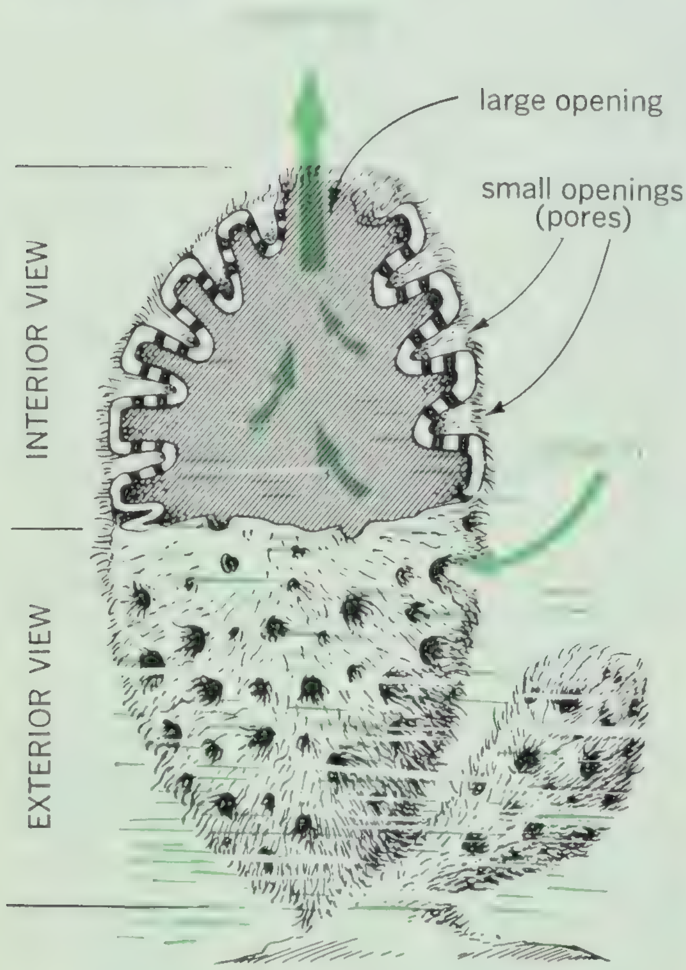
Protozoans are important because they serve as food for many larger animals. A few are harmful; for example, some are the cause of several serious diseases such as malaria and dysentery. Oil, which is now found in so many parts of the world, was formed from the bodies of protozoans that lived millions of years ago.

Sponges

Sponges, such as the large ones used for washing cars, are really the skeletons of marine sponges that grow in warm water. The soft, living body parts have been washed out. Most sponges live in the ocean. A few kinds are found in fresh water. All live attached to rocks in the water.

The bodies of sponges are composed of numerous cells. However, they are still very simple animals. Each sponge consists of two rows of cells around a central cavity. The outer layer of cells serves as a skin. The body of a sponge has many tiny holes and

Three kinds of protozoans are (left) four vorticella, (centre) a paramecium, and (right) an amoeba. Find one or more of these tiny one-celled animals in the illustration (above) of a drop of pond water. (Bausch and Lomb Optical Company photo)



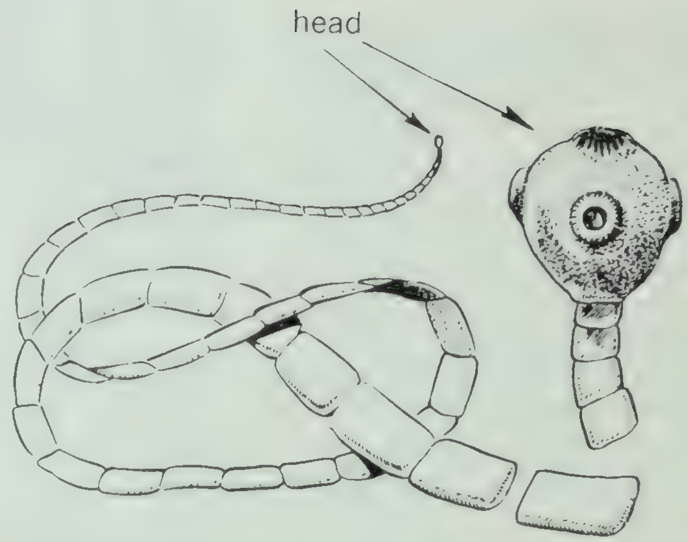
A diagram of a simple sponge. In what way do the cells of a sponge show specialization in the work that they do for the animal as a whole?

one or more large openings. Water, carrying food, flows in through the small holes and out through the larger openings. The inner layer of cells takes food from the water.

Flatworms and roundworms

What is a worm? Some people apply the name to all small animals with long, cylindrical bodies. However, caterpillars, such as cutworms, wireworms, and silkworms, are *not* worms. They are the larval stage of certain insects.

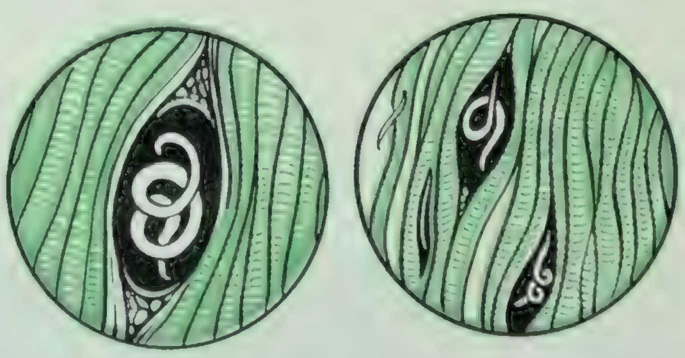
All worms have long, soft bodies. They have no skeletons and no legs.



The tapeworm is a parasitic flatworm. It has a long, flat body. The small, knob-shaped head is provided with suckers, and, in some kinds of tapeworms, with hooks. How does this animal secure its food? Why is it harmful?

Some have flat bodies. The bodies of others are cylindrical. Many live as parasites in the bodies of other animals.

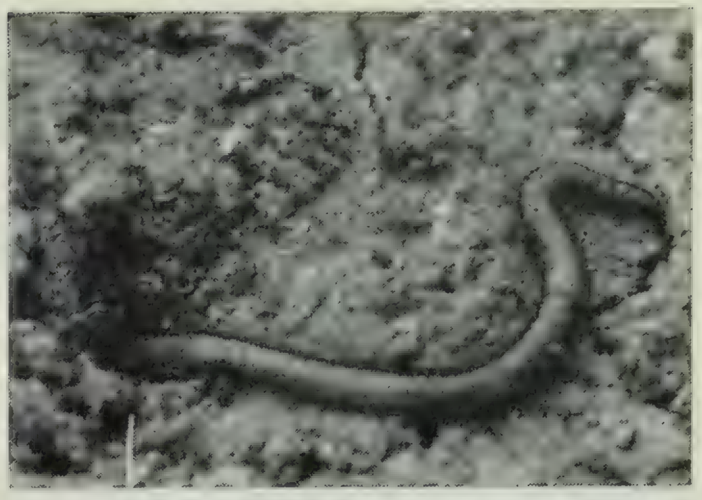
FLATWORMS — Flatworms have flat bodies. One harmless kind is about 1/4 inch long and lives in fresh water. A very harmful flatworm is the *tapeworm,* which may be from 1 inch to over 30 feet long. Tapeworms get into



A roundworm, known as the trichina worm, forms cysts or pockets in the muscles of pigs and rats. In the bodies of people, the worms come out of their cysts. They grow and produce many young. The young trichina worms bore into muscles all over the body. How do the worms in the cysts sometimes get from the muscles of the pig into the bodies of people?

the intestines of people and of other animals and live on partially digested food. *Flukes* are flatworms that get into the liver and other parts of the bodies of many animals, including man. The liver fluke is a serious parasite of sheep.

ROUNDWORMS — Roundworms have bodies that are long, slender, smooth, cylindrical, and pointed at both ends. Many live in the soil and in ponds and streams. If you examine some soil under a strong magnifying glass, you may see some roundworms. Some, such as *vinegar eels* and *horse-hair snakes,* are harmless. A very harmful roundworm is the *trichina,* which lives in the muscles of pigs and rats. It may get into the bodies of people who have eaten partially cooked pork in which the trichina is living. Trichina worms bore into the muscles and may cripple or even kill the human or other animal in which they are living.



To what class of animals does the earthworm belong? Why? Why is the earthworm considered to be a very useful animal?

Place several earthworms in a home similar to the one illustrated above. When you are not observing, keep the glass jar in darkness. By inserting layers of sand and soil, experiment to see how earthworms mix soil. Offer the earthworms lettuce or bread soaked in milk and buried in the soil

Segmented worms

These animals differ from flatworms and roundworms in that they have segmented bodies. Some live in the ocean, others in fresh water. The *earthworm,* which is the most important member of this animal group, is found in the soil.

Earthworms are easily observed on lawns at night, particularly on rainy nights. Use a flashlight and look sharply immediately after you turn it on. Earthworms may also be located and observed by digging in the soil. Other names for the earthworm are *night crawler, fishworm* and *angleworm.* You have probably used these worms as bait for fishing.

The bodies of segmented worms are divided into rings or segments. Almost all the segments of the earthworms are equipped with bristles. Watch an earthworm moving. First, the tail end of the body is held stationary by the bristles on the tail end segments. Then the head end of the body is extended forward and fixed in its position. The rear end of the body is then pulled forward. Put an earthworm in a shallow box with a layer of moist paper. Watch how it moves.

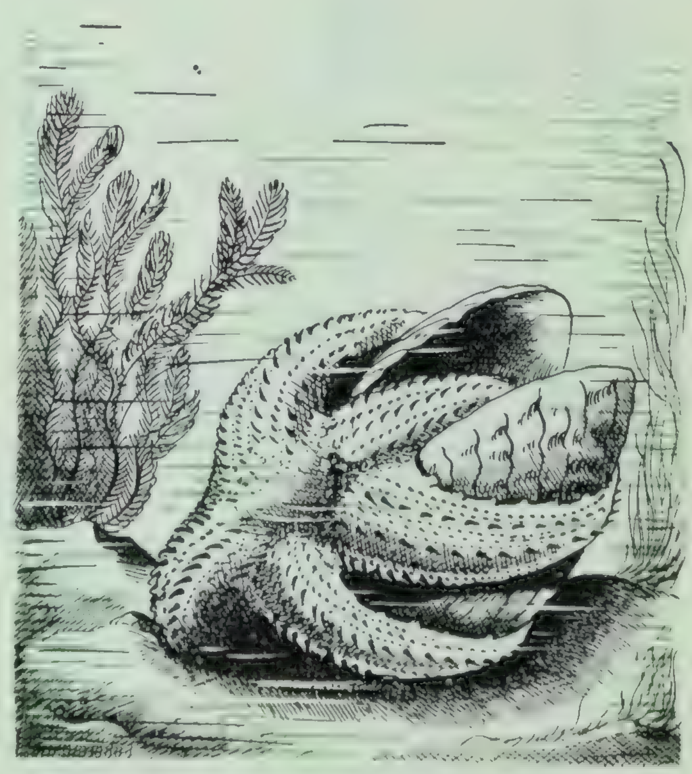
The food of earthworms is dead plant and animal material in the soil. They work their way through the soil and actually eat soil and pass it through their bodies. In this way, earthworms are most beneficial. They loosen and mix the soil. The soil that passes through their bodies is left at the surface in little heaps called *castings.* The great scientist Charles Darwin estimated that there are 50,000 earthworms in an acre of average soil, and that collectively they pass the equivalent of 18 large wagon-loads of soil through their bodies each year.

The earthworm is a more highly developed animal than those we have so far discussed. It has a digestive system, a circulatory and a nervous system. In other words, the cells in its body are more highly specialized. Each group of cells has its own special work to do to keep the earthworm alive. The earthworm breathes through its skin, which must always be moist.

Perhaps, sometime when you have been swimming, you have found a small animal stuck fast to your skin. This unpleasant animal is a *leech;* it is another kind of segmented worm. Leeches, which are often called "bloodsuckers," are equipped with a sucker at each end. The front sucker has cutting mouthparts with which to puncture skin and suck blood. Leeches attack fish, turtles, water birds, and man.

Spiny-skinned animals

Many animals in this group have a hard, shell-like skin covered with stiff, pointed spines. Others have a leathery body covering. Some of you have been to the ocean and have seen a *starfish* skeleton. The starfish is not a fish, and is never found in fresh



A starfish pulling open the hinged shells of an oyster in order to eat the fleshy parts inside. What adaptation of the starfish enables it to hold on to the oyster shell? Why do men who raise and gather oysters try to get rid of starfish?

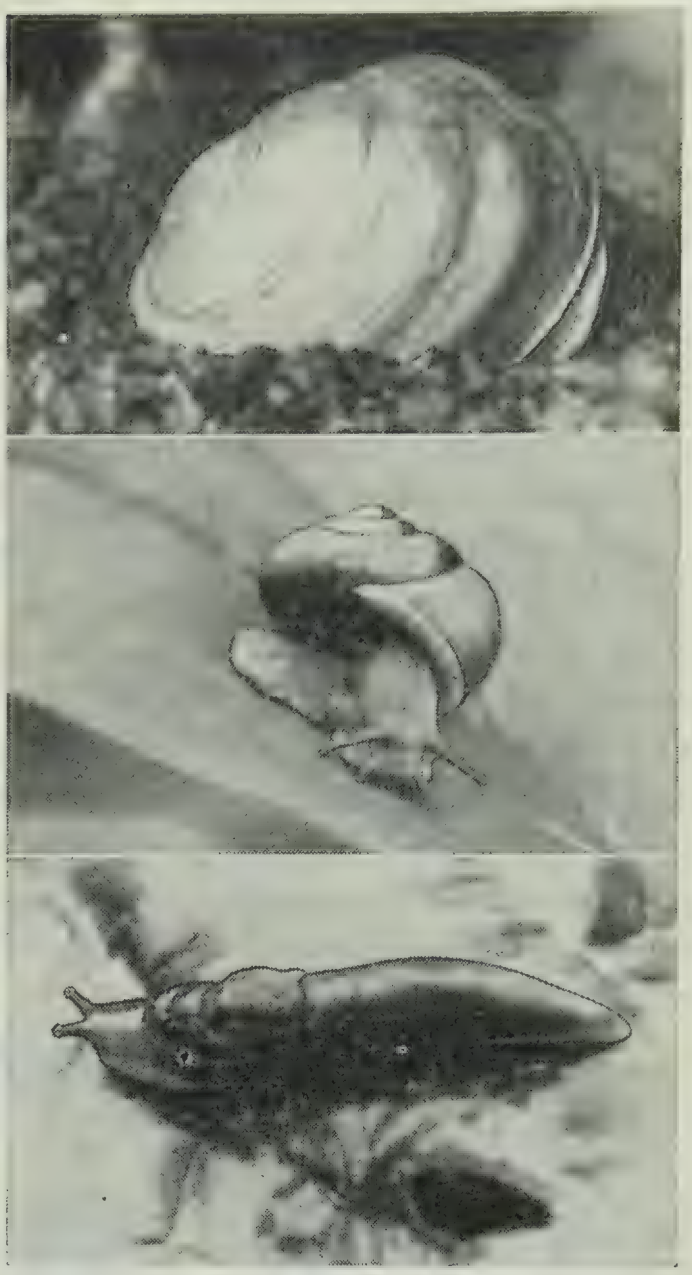
water. Each starfish has five movable rays or arms extending out from a hollow central body. On the underside of each arm are rows of tube feet ending in suckers. These suckers enable the starfish to cling to prey and even to pull open a clam or oyster shell in order to eat the soft body parts inside. The starfish is able to move about on the ocean floor.

Many other spiny-skinned animals live in the sea. Along the seashore may be found the skeletons of the *sand dollar, sea urchin,* and other spiny-skinned animals.

> Do not be satisfied merely to read about animals. Look for them in their natural surroundings as described in this chapter.
>
> If you bring live animals to school, be sure to take good care of them while you are making your observations.

Mollusks — the animals with soft, fleshy bodies

It is sometimes difficult to believe that there are so many kinds of animals. In each of the groups that we have studied there are several thousand kinds. There are 80,000 kinds in the group of mollusks, which includes clams, oysters, scallops, snails, slugs, squids, octopuses, and nautiluses. Most mollusks have hard shells, many of which are beautifully colored and shaped. Some have shells inside their bodies. Others have no shells.



Three mollusks are (top) the clam, (centre) the snail, and (bottom) the garden slug. Which of these animals has two shells? Which have one shell?

The three groups of mollusks are described in the paragraphs that follow.

One group has shells in two parts

The first group of mollusks has shells that are in two parts *held together by strong muscles and hinged to open and close.* This group includes *clams, oysters,* and *scallops.* These animals live on the bottom of shallow

bays of the ocean. Some clams live in the mud of lakes and streams. Clams have a foot and move about slowly. Oysters lack this foot and live attached to rocks. The shells are lined with a white skin-like *mantle.* The mantle forms the shells from lime taken from the water.

You probably know that true pearls come from oysters and clams. When a grain of sand gets in between the mantle and the shell, it causes irritation. The mantle then produces a smooth, shiny substance called *mother-of-pearl* to cover up the grain of sand. In this way a pearl is produced. Many people have opened a clam or oyster shell and found a pearl. Perhaps you have seen the beautiful mother-of-pearl lining of many shells.

Three kinds of snails. Why are these little animals useful in an aquarium? Watch a snail to see how it moves along on its one foot.

Another group has shells in one piece

The second group of mollusks includes *snails* and *slugs.* You may find several kinds of snails in ponds and on plants growing in moist places. Snails carry their shells on their backs and can withdraw into them for protection. They have a single foot which secretes a slime along which the foot slowly moves. The tongue of a snail has rows of sharp teeth and can scrape small plants off stones, cut larger plants into pieces, and even drill holes in the shells of other animals. A snail's eyes are on the tips of two horns on top of its head. Snails live in both salt and fresh water and on land. The shells of slugs are small, thin plates. These animals live in damp places — under leaves, logs, and stones. Sometimes they damage garden plants. At night, slugs leave "silvery trails." Why?

The third group has no shells or has shells inside their bodies

The third group of mollusks includes *squids* and *octopuses.* The foot of these mollusks is divided into long arms, or tentacles, projecting out from the head and body. The tentacles are provided with suckers for holding prey. Squids and octopuses can move with considerable speed by forcing water out of a tube. This method of jet-propulsion pushes the animals' bodies through the water.

Many mollusks, such as clams and oysters, provide us with food.

NOTE: There is another group of animals that are also invertebrates. They are the *arthropods,* or jointed-legged animals. They are so numerous and so important to us that we shall devote the whole next section of this chapter to studying them.

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. Name the two groups into which all animals are divided. What is the essential difference between the two groups?
2. What is the chief common characteristic of protozoans? In what ways are they helpful to man? In what ways are some of them harmful?
3. A sponge is a very simple animal, but it is more advanced than a protozoan. Explain.
4. In what ways are some flatworms and roundworms harmful?
5. To what group of invertebrates does the earthworm belong? The earthworm has been described as "nature's ploughman." Explain.
6. By describing how a starfish captures and opens a clam or oyster shell, explain how it is adapted to its way of living.
7. Name a common member of the mollusk group of animals. Describe how it is adapted to live in its surroundings. Of what value to man are mollusks?
8. How does an oyster produce a pearl?

ARTHROPODS — ANIMALS WITH JOINTED LEGS

These invertebrates are by far the largest group of animals. They include some 700,000 kinds.

SOMETHING TO DO

Study the diagram on page 38, and point out as many differences as you can among the four groups of jointed-legged animals. Watch for other examples of each group.

The arthropods have three common characteristics:

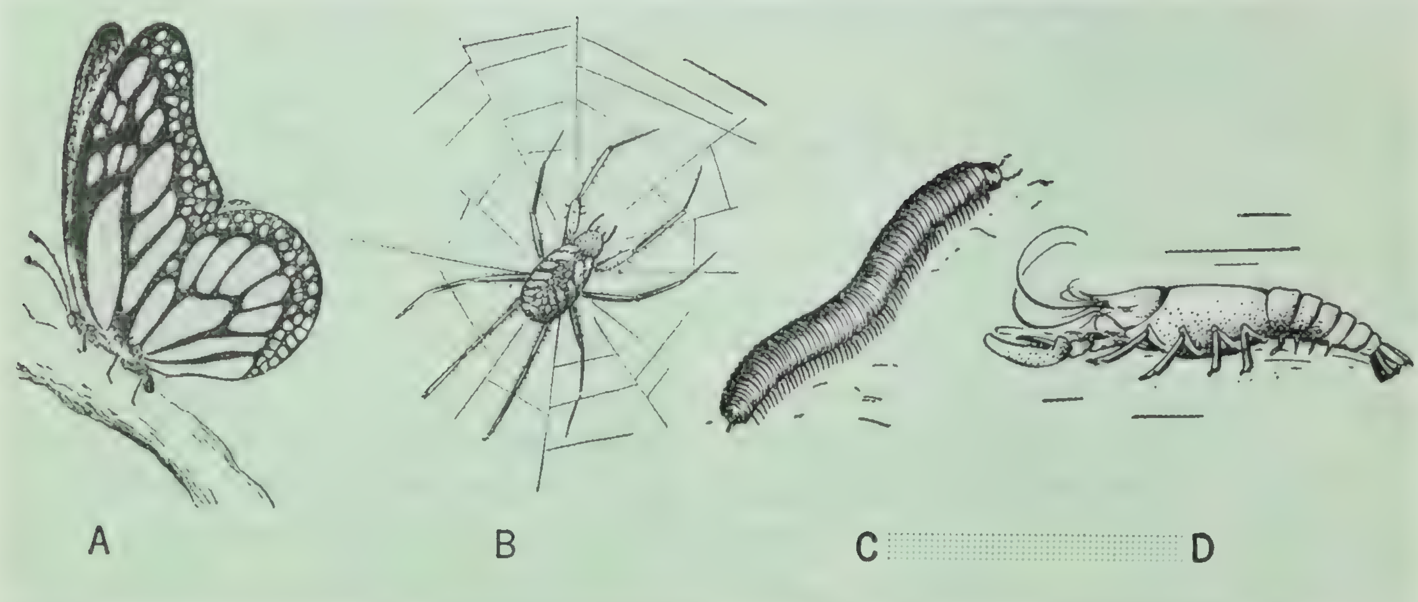
1. jointed legs.
2. external skeletons — their skeletons are on the outside and cover the softer body parts like a suit of armor.
3. several body parts: some have three body parts — the head, thorax, abdomen. Sometimes the head and thorax form one part. In other cases, the thorax and abdomen make up a single part.

The arthropods are more highly developed than the other animals that we have studied so far. They have a muscular heart and well developed circulatory, nervous, and digestive systems. They can see, hear, feel, taste, and smell.

There are four groups of arthropods.

Crustaceans, or "crusted animals"

A good example of a crustacean and the one that you will likely see most frequently is the *crayfish*. Other examples of crustaceans are *lobsters*, *crabs*, and *shrimps*.



This drawing illustrates examples of the four groups of arthropods, or jointed-legged animals: A. a monarch butterfly, an insect; B. a common garden spider; C. a millipede, one of the many-legged animals; D. a crayfish, a common crustacean. Name other animals in each group.

SOMETHING TO DO

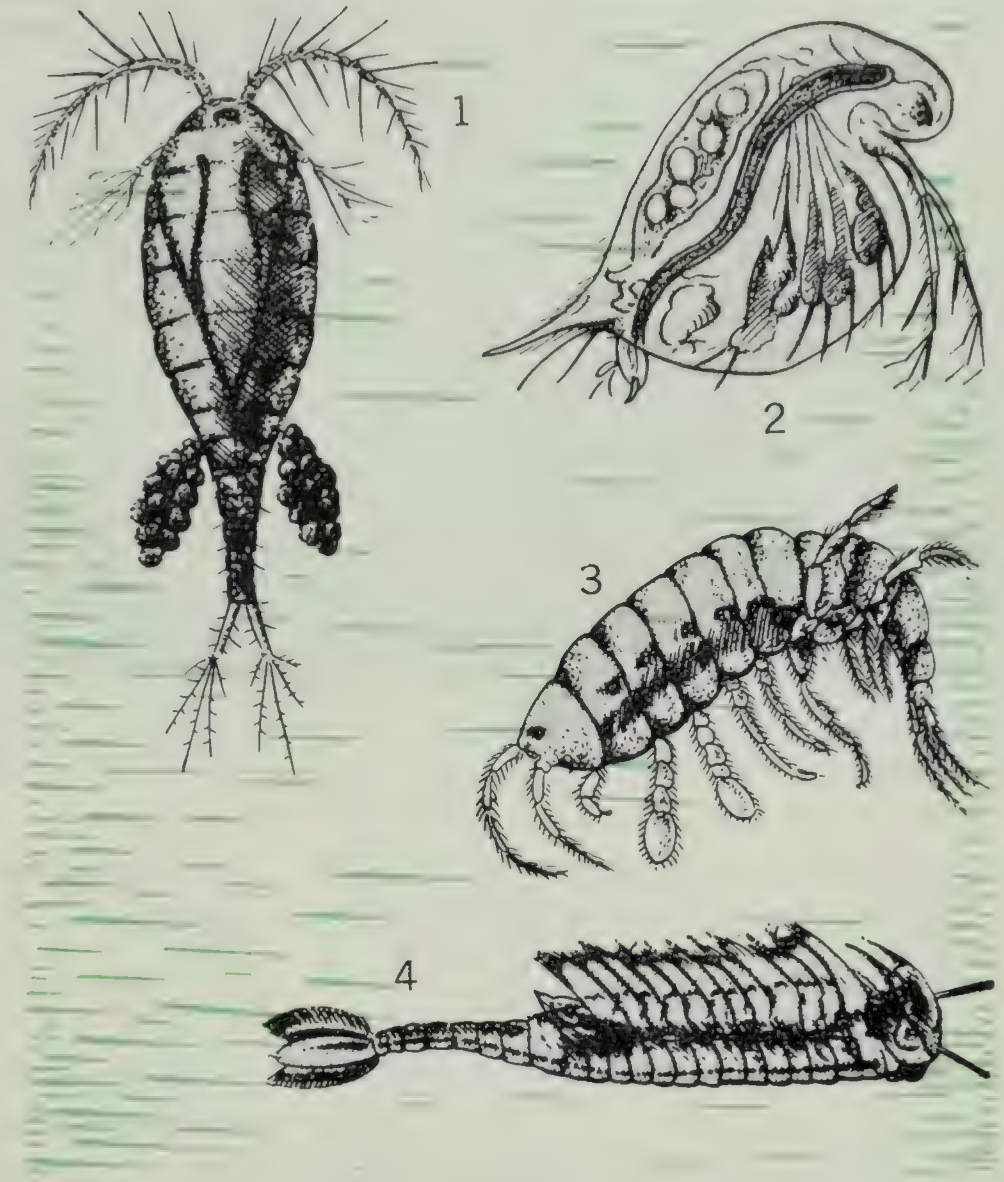
Find a crayfish and observe it. It may be kept in an aquarium, but do not put other aquarium animals with it.

Crayfish may be seen in the water or burrowing in the mud of nearly all lakes, ponds, and rivers. They have strong, flexible, external skeletons. When young crayfish grow as large as they can inside their skeletons, they molt — that is, they shed their skeletons. Then they form new skeletons and grow until they fill them, when they molt again.

Crayfish have five pairs of legs. The two front legs are provided with large claws. If a crayfish loses part of

The crayfish is one of our best known crustaceans. Notice its antennae, its eyes, its pair of large front legs, and its other four pairs of legs.

Be sure to watch for these tiny crustaceans: 1. cyclops: is about 1/5 of an inch long, has a single eye in middle of its head, is usually yellow or greenish, and swims in jerky fashion; 2. daphne, or water flea: is about 1/16 of an inch long, has an almost transparent covering, an oval body with a tail spine, and swims jerkily; 3. fresh-water scud, or shrimp: is one of the most common of the tiny crustaceans, is about 5/8 of an inch long, brownish color, and found on the bottoms of ponds and sloughs; 4. fairy shrimp: is usually less than ½ inch in length, has an almost transparent body, is graceful, swims on its back, and sometimes is a shiny pinkish-green.



a leg, a new part develops. The tail flippers can propel the crayfish swiftly backward.

Under the external skeleton of the crayfish are external gills, by means of which the crayfish takes in oxygen from the water and gives off carbon dioxide. Crayfish feed upon dead or living plants and animals that they find in the water.

Lobsters, crabs, and shrimps furnish us with a great deal of food. The kinds that we eat come from shallow bays along the coast of the ocean.

The numerous tiny crustaceans of inland ponds, lakes, and sloughs are interesting animals. They include *cyclops, daphne* or *water fleas, fresh-water scuds,* and *fairy shrimps.* They are common in fresh water pools, and often appear in large numbers in prairie ponds. They survive long droughts and cold winters by means of special thick-shelled resting eggs. The eggs lie dormant in either dry or wet soil. Eggs of fairy shrimps have remained alive for a dry period of 14 years. When favorable conditions return, the eggs hatch. These minute crustaceans serve as food for small fish, and are in demand by aquarium owners.

The lobster is a large crustacean. Compare its size with that of the fairy shrimp and other crustaceans shown on page 39. How is a lobster adapted to live in the water? (National Film Board photo)

SOMETHING TO DO

Look in sloughs and other small bodies of fresh water for small crustaceans. Use the information outlined in the foregoing paragraph and in the drawing on page 39 to identify the kinds mentioned.

Centipedes and millipedes

As their name suggests, these are many-legged animals. Their bodies are divided into many segments.

Centipedes, or "hundred-legs," do not always have 100 legs. Some have 30, others as many as 300. You may find centipedes under logs, stones, or other similar dark, damp places. You will have to look sharply for them as they are quick-moving little animals. They eat small, soft-bodied animals.

Millipedes, or "thousand-legs," are not equipped with 1000 legs. Each body segment has two pairs of legs with a total of several hundred. They live, as centipedes do, in dark, damp places, but eat plant food rather than other animals. In spite of all their legs, millipedes do not travel as rapidly as centipedes.

Be sure to watch for centipedes and millipedes.

Arachnids, the spider group

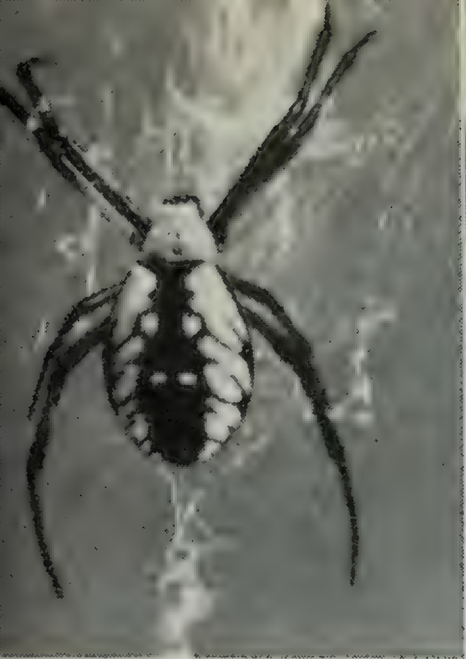
Spiders, scorpions, mites, ticks, and *"daddy-longlegs,"* are included in the many kinds of arachnids.

The commonest members of this group are the spiders. Spiders are not the same as insects. How are these two groups of animals different?

SOMETHING TO DO

1. Confine a spider and a grasshopper (or other insect) under tumblers. Observe each carefully. How many legs has each? How many body parts? Which has wings? Which has antennae, or feelers?
2. Study spiders' webs. How are they suspended? Which threads are dry? Which are sticky? Look for funnel webs in the grass.

You will have observed that spiders and insects differ as follows:



Above, a garden spider. How does a spider differ from an insect? Right, a spider's web? Which are the dry supporting threads? Which are the sticky threads? Spiders are useful animals. Why?

Spiders. — 8 walking legs, 2 body parts (the head and thorax are joined), no wings, no antennae.

Insects. — 6 walking legs, 3 distinct body parts, antennae, many have wings. (We shall learn more about insects in the next section.)

Spiders are easily observed. They are not dangerous to man as many people wrongly believe, although the bite of some can be painful. Many spiders spin webs to capture flying insects. The webs are a marvel of engineering skill. Try to watch a spider spinning its web. The silk is a liquid produced from spinnerets located near the end of the body. As soon as it is exposed to the air, the liquid hardens to form a strong thread of silk. To construct a web, a spider first strings dry, strong, foundation threads between suitable supports and then builds in the radiating spokes. Finally, sticky spiral threads are added to complete the web. When insects become entangled, their struggles wind more and more of the sticky silk around them. Spiders are provided with a pair of fangs with which to inject a poison into their prey to paralyze it.

With few exceptions, spiders are extremely beneficial, as they destroy large numbers of harmful insects.

Ticks live on, and suck blood from, chickens, dogs, cattle, and people. Scorpions have a stinger at the tip of the abdomen. Their stings are painful but seldom fatal.

Insects

More than half of all the kinds of animals are insects. While there are few insects in the ocean, they are widely distributed on land and in fresh water.

By looking carefully at clear, still water you can find and observe these water insects: 1. water strider, which walks on top of the water; 2. May fly nymph (see photograph of adult May flies on page 48); 3. mosquito larva and pupa; 4. backswimmer, 5. water boatman (these insects resemble each other in appearance); 6. whirligig beetle, which, like other beetles, has hard wing covers; 7. diving beetle, which, under its wing covers, carries air which it breathes while in the water; 8. caddis fly: *(a)* larva, which builds a protecting case of tiny sticks or leaves and *(b)* adult leaving the water; 9. giant waterbug, which is 2 or 3 inches long and is often seen flying around electric lights.

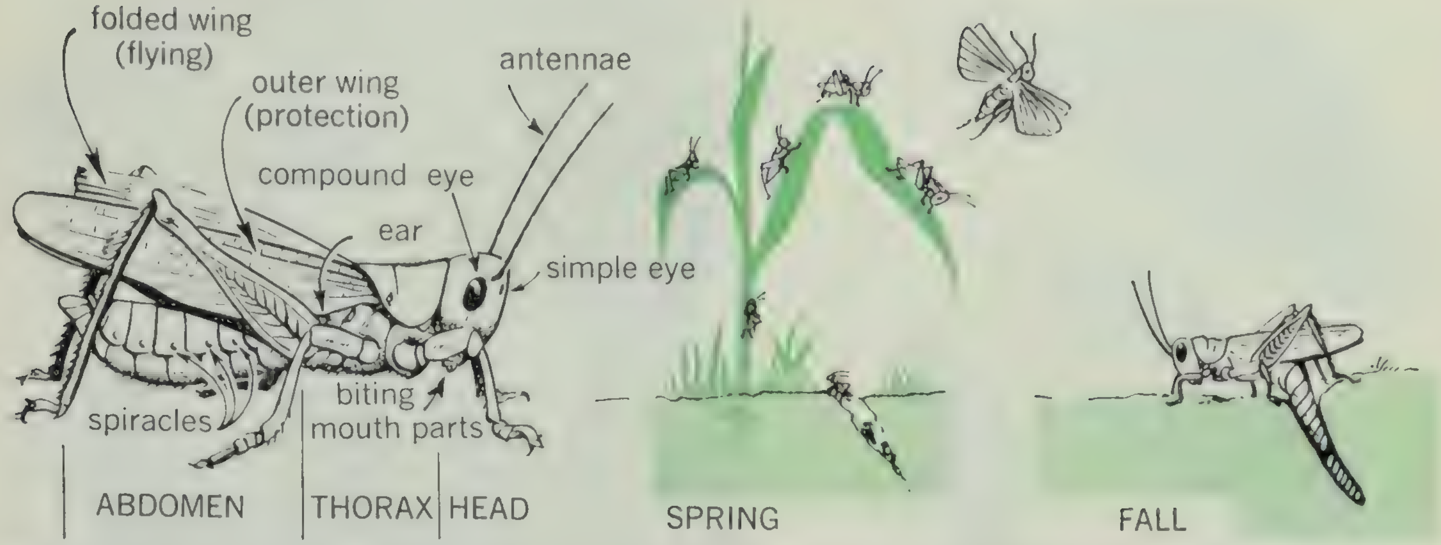
Insects are able to survive in great numbers for several reasons. They are so small that they can readily hide away from enemies. They lay large numbers of eggs and reproduce rapidly. They can successfully withstand many unfavorable weather conditions.

SOMETHING TO DO

Observe a number of insects. Then write out a list of all the characteristics of insects that you know. Compare your list with the outline that follows.

All insects have *6 legs.*

All insects have *3 distinct body parts* — head, thorax, and abdomen.



The body parts and life story of a grasshopper. The young grasshopper, or nymph, is much like the adult. The grasshopper, therefore, is said to undergo an incomplete metamorphosis. How does this insect breathe? How does it travel? How does it see and hear?

Insects have a pair of antennae, or feelers.

Most insects have two compound eyes made up of many tiny eyes.

Many also have three simple eyes.

Most insects have two pairs of wings. Some have one pair. Some have no wings.

Some insects, such as grasshoppers and cutworms, have chewing mouth parts. Others, such as mosquitoes and butterflies, have sucking mouth parts.

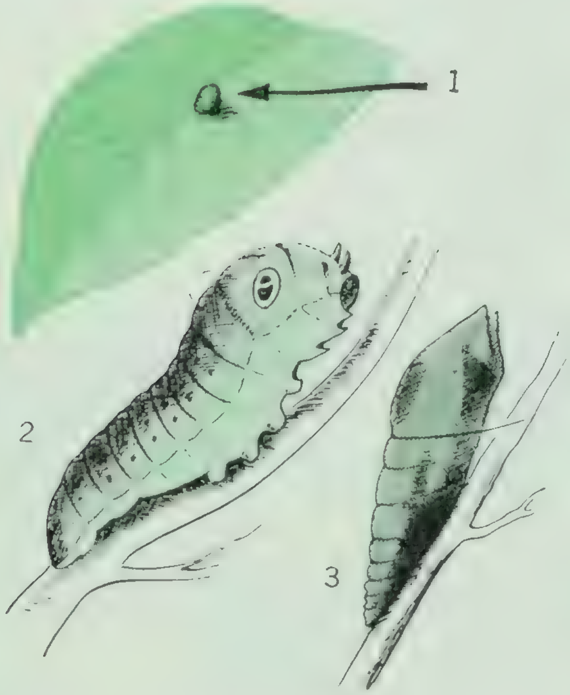
Insects breathe through holes along the sides of their bodies.

Insects hatch from eggs, and undergo changes in form as they grow into adults.

The change in form which insects undergo is known as a *metamorphosis.* Some young insects, such as grasshoppers, closely resemble the adults. They do not change greatly and are said to undergo an *incomplete metamorphosis.* They pass through three stages: *egg, nymph* (or young), and *adult.* Others, such as butterflies, moths, flies, and beetles, pass through a *complete metamorphosis.* For example, caterpillars change to butterflies or moths, grubs become beetles, maggots change to flies. These insects pass through four stages: *egg, larva, pupa,* and *adult.*

Insects, like the other animals that we have been studying, exhibit many remarkable adaptations. Some examples are: the jumping legs of the grasshopper, the hard wing-covers of the beetles, the long, coiled tongue of the butterfly, the marked resemblance of some insects to twigs and dead leaves, and the rapid flight of flies and bees. What other adaptations of insects can you mention?

As you have learned, there are a great many kinds of insects: grasshoppers, dragonflies, butterflies, bees, moths, beetles, ants, wasps, flies, mosquitoes, and numerous others. Some of these are very destructive, but many other insects are most useful.



The tiger swallowtail butterfly is a good example of an insect that undergoes a complete metamorphosis. 1. Small, single *eggs* are laid on leaves of such trees as birch, poplar, ash, and cherry. The eggs hatch in about 10 days. 2. The *larva* is a green caterpillar with two large eye-like spots at the front end. When it is disturbed, its front end sways back and forth, and two soft, orange-colored horns are forced out on its head. The larva's length when full grown is about 2 inches. 3. When mature, the caterpillar forms a *chrysalis,* about 1¼ inches long, which hangs erect within a loop of thread. The tiger swallowtail usually winters in this stage. The adult is a large *butterfly,* as shown in the photograph at the right, above. It has a wingspread of 5 inches. Its wings are yellow with black borders and black cross stripes, and its hind wings have a ½ inch tail.

Face to face with a butterfly. Find the antennae, the compound eyes, and the coiled feeding tube. (photo by C. G. Hampson, University of Alberta)

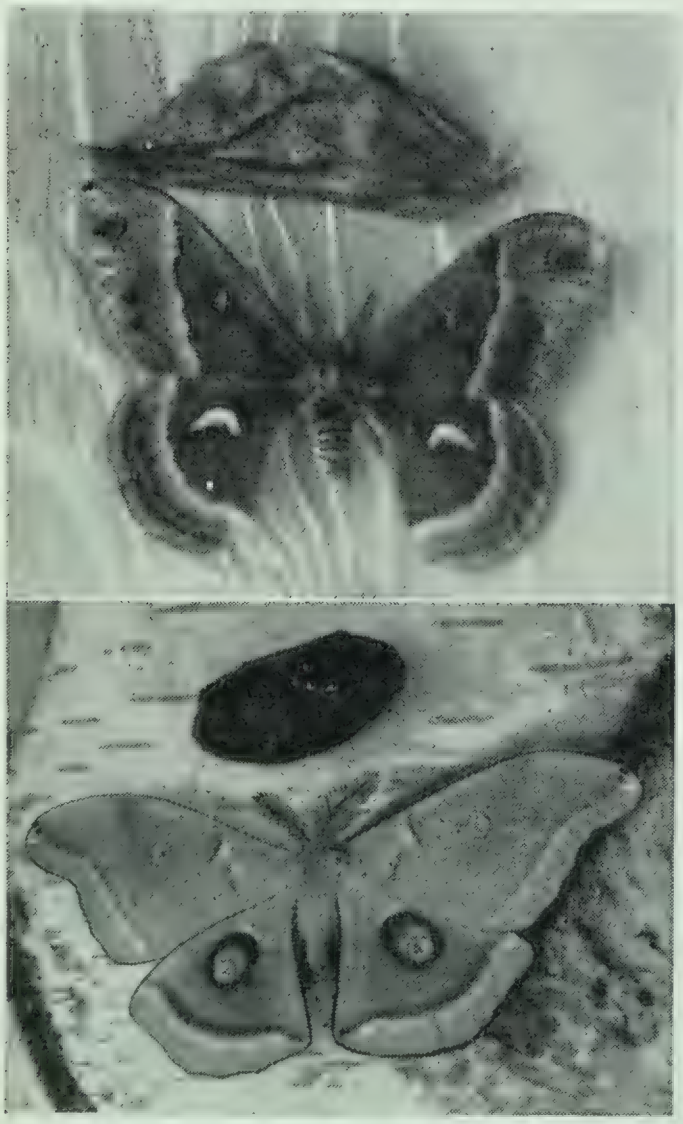
Watch for the butterflies shown at the left (reading from top to bottom). The large banded purple, or white admiral, has purple wings with white bars. The medium-sized clouded sulphur has yellow wings with black borders. The large mourning cloak has purplish-brown wings with yellow borders. The large viceroy has orange-brown wings with black veins. This butterfly resembles the monarch (shown beside it), but differs from it in that it has black cross bars on its hind wings. The monarch (beside the viceroy) has large, reddish-brown wings with black veins and borders. The small cabbage butterfly has white wings with one or two spots.

Insect characteristics

How Do Insects See? — Some insects have simple eyes only. They do not see very well. Other insects have compound eyes as well as simple eyes. Their compound eyes are made up of small eyes numbering from a few to many thousands. Compound eyes enable insects to see fairly well. Each small eye in a compound eye sees a small part of an object. The brain of the insect then fits all the parts into one picture. What insects with compound eyes do you know?

How Do Insects Hear? — Some insects have ears, but you will be interested to know that their ears differ from ours and are located on different parts of their bodies. One kind of grasshopper and some moths have ears on their abdomens. Other kinds of grasshoppers, katydids, and crickets have ears on their front legs. The male mosquito hears by means of tiny hairs on its antennae.

How Do Insects Breathe? — Most insects breathe through tiny holes, called *spiracles*, in the sides of their



Two large silk moths that you should know are the cecropia and the polyphemus. The *cecropia* (top) has a wingspread up to 6½ inches. It is grey-brown, with a large red-and-white crescent on each wing. Its abdomen is red with black bands. Its cocoons are tough, papery, and pointed. The *polyphemus* (bottom) has a wingspread up to 6 inches. Its grey-brown forewings have transparent yellow-bordered eye spots; its black-bordered hind wing has a blue spot resembling an eye. Its cocoons are strong and oval.

abdomens. Little sacs inside their bodies expand and contract and pump air in and out of the spiracles. Fine tubes then carry the air to all parts of their bodies to supply the cells with oxygen and carry away the waste carbon dioxide. You can easily see spiracles on large, bare-skinned caterpillars, on large grasshoppers, and on the sides of chrysalides and other pupae. Some adult water insects carry air with them when they dive into the water. Mosquito larvae and pupae breathe through short tubes which they thrust up to the surface of the water. Some young water insects have gills.

How Do Insects Communicate?—A bee that has discovered a rich supply of food can tell other bees about it. Grasshoppers can hear sounds made by other grasshoppers. Female mosquitoes hum by moving their wings very rapidly. Male mosquitoes hear this sound and fly to the females. The females of the large native silk-moths (cecropia, polyphemus, promothea) send out through the air an odor-message to which the male moths respond. Female fireflies flash their lights to signal to the male fireflies. Male cicadas have "drums" on their abdomens and on hot days produce loud, buzzing sound-signals to the females.

How Do Insects Move About? — You have probably seen a caterpillar walking or crawling along a leaf or twig. Did you ever notice a caterpillar that travelled by stretching out the front part of its body, then looped its body, and in this way pulled the hind end forward? Caterpillars that move in this way are called *loopers* or *measuring worms.* Both land and water insects use their legs to walk, jump, or climb. Dragonfly nymphs force jets of water from their bodies

A giant water bug with its eggs. The adult, which is 2 inches or more in length, is broad, flat, and brown, with strong middle and hind legs that are suitable for swimming. Its beak is suited for sucking juices out of small fish, frogs, and other insects. The water bug is sometimes seen flying around strong lights. (Canada Agriculture photo)

to push themselves rapidly through the water. Diving beetles, water boatmen, and back-swimmers have flattened and fringed legs which they use as oars. As you know, many insects have wings for flying. Mosquitoes and flies have only two wings, but most insects have four wings.

A tiger moth laying her eggs. Why is it necessary for insects to lay so many eggs? (C. G. Hampson photo)

How Do Insects Feed? — Several kinds of wasps sting other insects such as caterpillars and grasshoppers and store them in their nests where they lay their eggs. When the young wasps hatch, they feed upon the stored insects. Caterpillars, grasshoppers, beetles, and other insects have biting mouth parts. They bite off pieces of leaves and chew them. A great many plants are destroyed in this way. Numerous other insects have sucking mouth parts. Many butterflies suck nectar. Mosquitoes suck blood and the juice of plants. Aphids also suck plant juices. The tongue of the bee enables it to lap up nectar. Houseflies have a lower lip that forms a sucking tube.

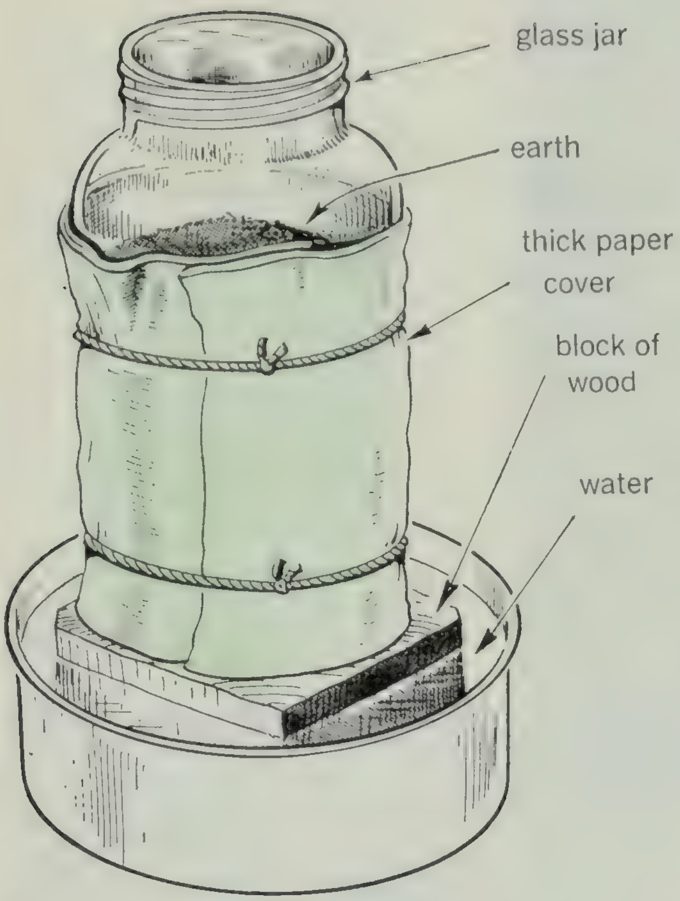
How do insects assist man?

Many insects annually cause damage to field and garden crops amounting to millions of dollars. Other insects, however, are decidedly beneficial and of value in many ways.

May flies have thin, delicate wings and two or three long delicate "tails." May fly nymphs live in the water (see illustration page 42).

This drawing shows part of an anthill. 1. larvae; 2. cocoons; 3. worker; 4. queen. Depending upon the kind of ant, winged adults, queens, and males may be observed, often in large numbers, during spring, summer, and fall.

Ants often feed upon honeydew, a sweet liquid produced by aphids, which are sometimes referred to as the ants' cows. (Hugh Halliday photo)



Prepare a classroom anthill. Dig into an ant-hill to obtain soil and ants. If possible, find the queen, which is larger than the workers. Feed the ants bits of bread, sugar, honey, and dead insects. From time to time, take off the paper cover to observe the tunnels made by the ants.

Honey bees are our most useful insects. As early as Biblical times, man used honey from both wild and domesticated bees. Today, bee-keeping is a scientific undertaking. Rectangular wooden hives provide ample room for both the rearing of the new brood and the storing of quantities of honey.

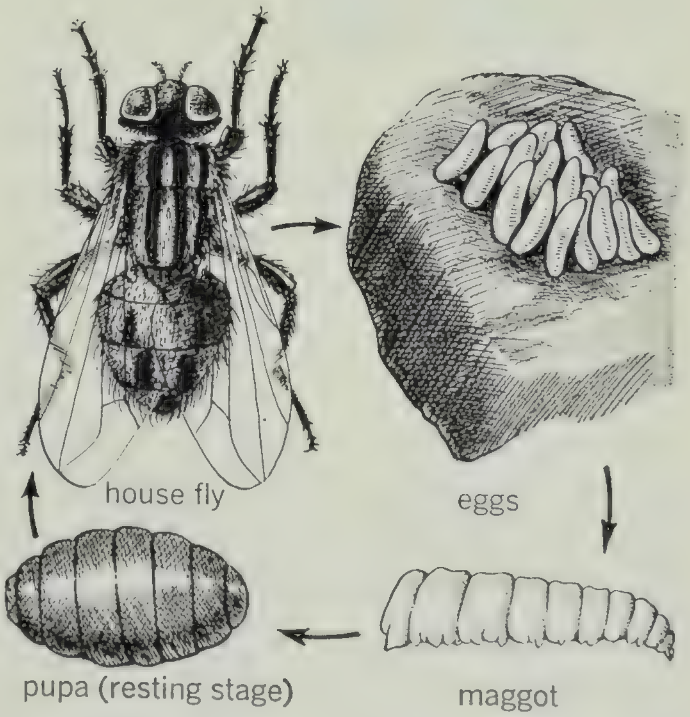
Bees are beneficial in another and very important way. Honeybees and certain kinds of wild bees, such as *bumble-bees* and *leaf-cutter bees,* render man invaluable service by helping to pollinate the flowers of alfalfa, fruit trees, and other crop plants. Many orchard owners keep several hives of bees to ensure the pollination of the flowers on their fruit trees. When there are leaf-cutter bees living near fields of alfalfa, bigger crops of seeds are produced.

SOMETHING TO DO

Observe bees gathering nectar and pollen. Do not excite or anger them, and they will not sting you.

You may be able to watch a bee filling the pollen baskets on its hind legs or gathering nectar from a flower.

Confine a bee under an inverted tumbler or in a suitable cage over a growing clover plant. Do not injure her;



Stages in the life of a house fly. A house fly ejects juices onto its food to dissolve it, then sucks it up. This insect carries filth and disease germs from place to place, and should be destroyed by every possible means. It has been estimated that one house fly could produce 5½ trillion descendants between early spring and autumn.

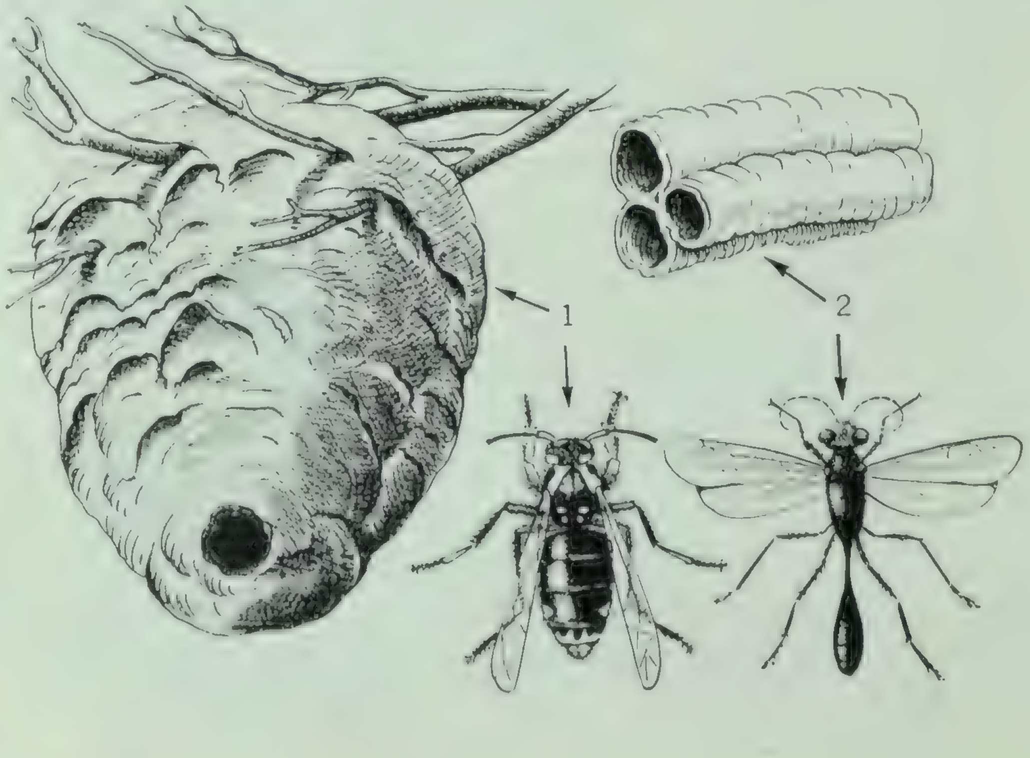
Why do bees and other insects visit flowers? What useful work do they do for the flowers? (Hugh Halliday photo)

release her when your observations are complete.

See Chapter 8 for suggestions for further studies of bees.

Silk has been in use for nearly four thousand years. The early Chinese first learned the secrets of silkworm culture and for a long time kept the knowledge to themselves. Later, Japan and southern Europe became, with China, the largest producers of silk.

The *silkworm*, as you know, is not a worm but the caterpillar of a small, greyish-white moth. The moth lays some 500 tiny eggs. From the eggs



1. The adult paper-making wasp and its nest. To make the paper for its nest, this wasp chews up tiny bits of wood and mixes it with a liquid in its mouth. 2. The adult mud - dauber wasp and its nest. This wasp uses mud mixed with the liquid in its mouth to make its nest.

Below: An adult dragonfly. Dragonflies may be confused with damsel flies. Distinguish them by remembering that the wings of the dragonfly at rest are held horizontally, while the wings of a damsel fly are held vertically. Dragonfly nymphs live in the water. They have a hinged lower jaw that can be thrust forward to capture small water animals upon which the nymph feeds (see page 52). Right: When the dragonfly nymph is ready to molt for the last time, it leaves the water, and the adult emerges. At first, the wings are small and shrunken.

hatch small, dark caterpillars which feed hungrily on mulberry leaves. The caterpillars spin cocoons using great lengths of silk thread. In the production of silk, the pupae in the cocoons are killed by heat, and the cocoons are soaked in warm water to soften the thread so that the silk can be loosened and wound on reels. Many strands from the cocoons are twisted together to make one strong thread for weaving or sewing. If the pupae are not destroyed, the moths will develop and cut their way out of the cocoons, thus breaking the threads. Man-made fibres, such as nylon and rayon, are now used for many articles which were previously made of silk.

Many insects are useful to man because they feed upon other insects that are harmful. The *praying mantis* eats other insects. Its front legs are held in a position suggesting prayer, but actually they are raised in readiness to seize and hold its prey. *Dragonflies* are swift in flight. As they fly, they fold their legs to form a basket under their chins and thus scoop up numerous mosquitoes and other small insects. The small, red-and-black *ladybird beetle,* sometimes wrongly called "ladybug," feeds upon aphids, or plant lice, which are very destructive. In California, ladybird beetles are collected and used to control aphids in orchards and gardens. In Australia, ladybird beetles are

Upper left, a damsel fly nymph. Lower left, a dragonfly nymph thrusts out its lip to catch a mosquito larva. Right, an adult damsel fly. Compare the position of its wings with the position of the wings of the dragonfly on page 51.

grown and shipped to other countries which value them as lice controllers.

Man has made extensive use of his knowledge of parasitic insects (insects that live upon other insects) to help him control harmful insects of the farm and forest. At several places across Canada, Dominion entomological laboratories have been established to study different kinds of parasitic insects and conditions in which they will thrive, and to find methods of using them to control harmful insects.

The long - horned beetle is an insect with very long antennae. The larva of this beetle bores into the wood of evergreen trees. (C. G. Hampson photo)

There are many kinds of beetles, two of which are the Colorado potato beetle (above) and the blister beetle (right). One pair of wings forms a hard cover to protect the flying wings underneath. You can easily observe the life cycle of the potato beetle (often wrongly called the potato bug). Its eggs are laid on potato plants. The larvae feed on the leaves. The pupa, or resting stage, is passed in the ground. The adult also feeds on potato leaves. Blister beetles, too, are harmful, as they eat the leaves of many plants.

The dainty ladybird beetle, which is often wrongly called "ladybug," is small in size and red-and-black in color. Ladybird beetles are extremely beneficial insects. They feed upon aphids, or plant lice, which cause great damage to many kinds of plants by sucking sap from stems and leaves.

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. What are the four groups of arthropods? What is their chief common characteristic?

2. Select one of the tiny crustaceans found in prairie ponds and sloughs, or another member of this group. Explain how it is adapted to its way of living.

3. (*a*) How are earthworms different from cutworms?
   (*b*) How are spiders different from insects?

4. Describe how a spider builds its web. In what way is this arachnid useful to man?

5. Compare a centipede and a millipede in respect to: body, legs, where found, food.

6. Insects are the most numerous group of animal. What are the adaptations of insects that make them so successful?

7. All of the groups of animals that we have studied so far in this chapter are invertebrates. Make a list of ways in which invertebrates are useful and in which they are harmful to man.

VERTEBRATES — ANIMALS WITH BACKBONES

The vertebrates are the largest, and therefore the most conspicuous animals. Each of them has a backbone composed of bone and cartilage. Each part of the backbone is called a *vertebra.* Extending through the vertebrae (plural of vertebra) is a spinal, or nerve cord.

All vertebrates can be classified into five groups: *fish* (the lowest group), *amphibians, reptiles, birds,* and *mammals* (the highest group). All the members of each group are alike in certain ways, and all are different from all other groups.

SOMETHING TO DO

1. Think of the groups of vertebrates that you now know. How are the members of each group alike?

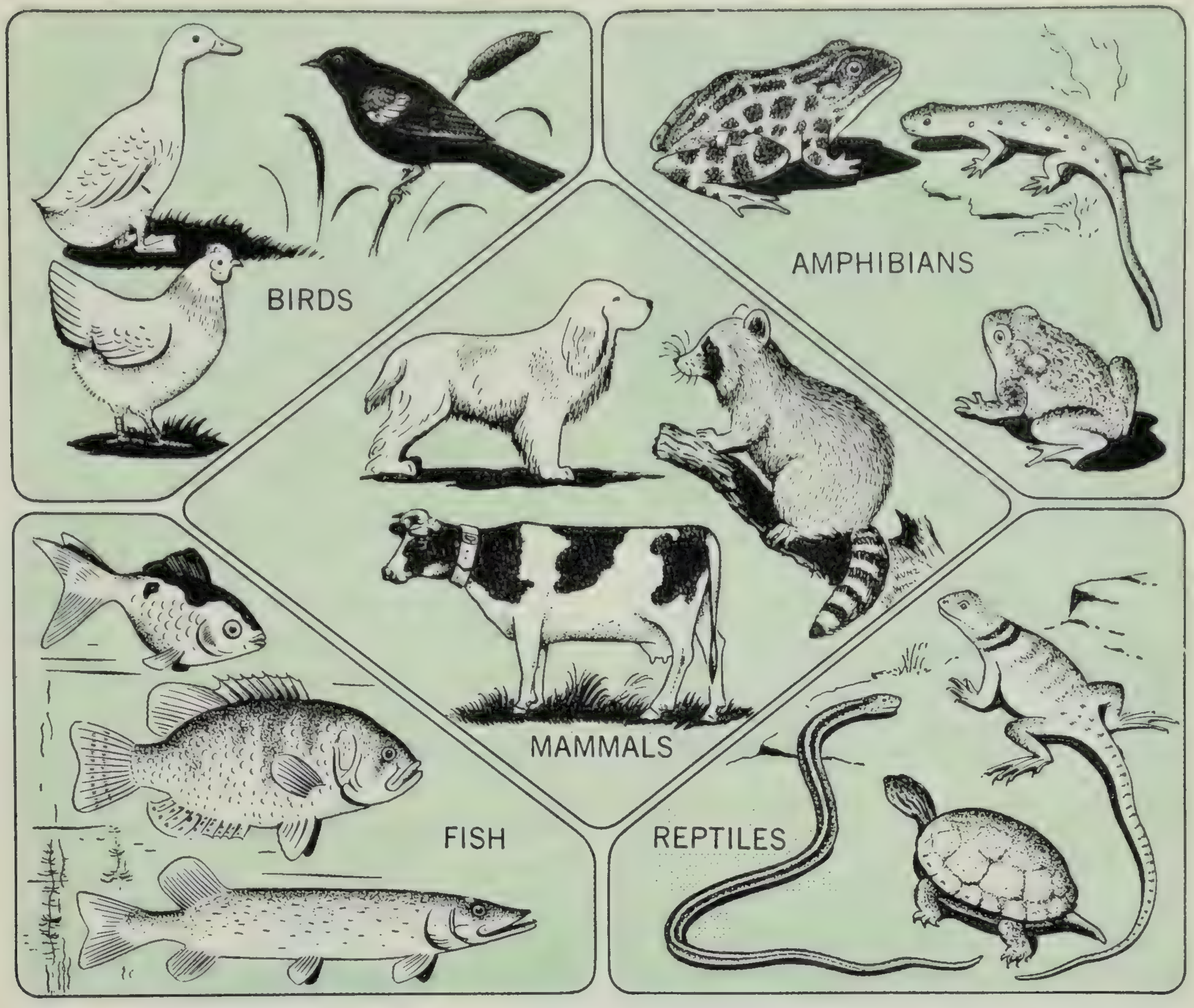
How are all fish alike? Consider their body covering, method of breathing, shape of body, reproduction, and the environment in which they live.

How are all birds alike with regard to body covering, shape of body, bills, feet, reproduction, and other characteristics?

In what respects are mammals (horses, dogs, beavers, apes, buffalo, man, etc.) alike?

2. Study the drawing of the five groups of animals with backbones on page 55. Name several additional animals in each group. To discover the characteristics of the five groups, compare the appearance and habits of the animals in each group.

If you have carefully observed the appearance and habits of various



The five groups of vertebrates. What are the characteristics of each group? Which two groups are warm-blooded?

groups of vertebrates, you will have discovered some of the characteristics of the five groups that will be discussed in the sections that follow in this chapter.

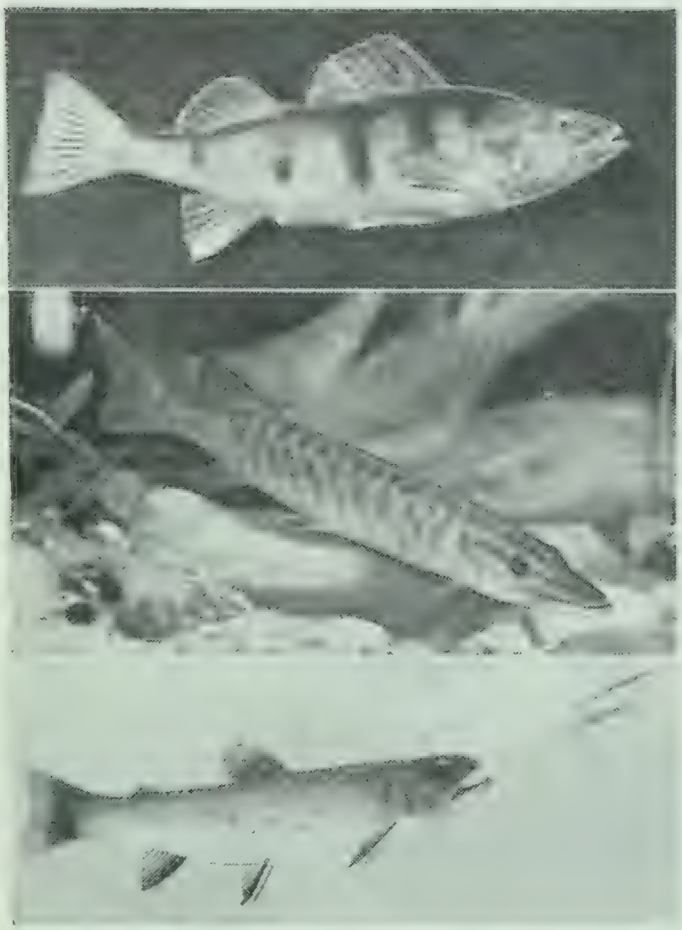
Fish

This group of vertebrates, which includes the bony fish, lungfish, lampreys, sharks, and rays, all live in water — some in salt water, some in fresh water, and some in both. They are considered to be the lowest group among the vertebrates. It is believed that they were the first vertebrates to appear on earth.

Fish are *cold-blooded*, which means that their temperature varies, rising and falling as the temperature of their surroundings become warmer or colder.

How fish are fitted for life in water

Fish are remarkable creatures, for they can glide through water as readily as birds sail through air — an



The yellow perch (top), which is less than a foot in length, is one of the fish that a beginning angler is likely to catch. The muskellunge (centre) is over a yard in length. Its barred pattern helps to distinguish it from the northern pike. The brook, or speckled trout, in the bottom picture is about to catch two minnows. (Photos by the authors and the National Museum of Canada)

amazing feat, because water is about 800 times as heavy as air and therefore offers much greater resistance.

SOMETHING TO DO

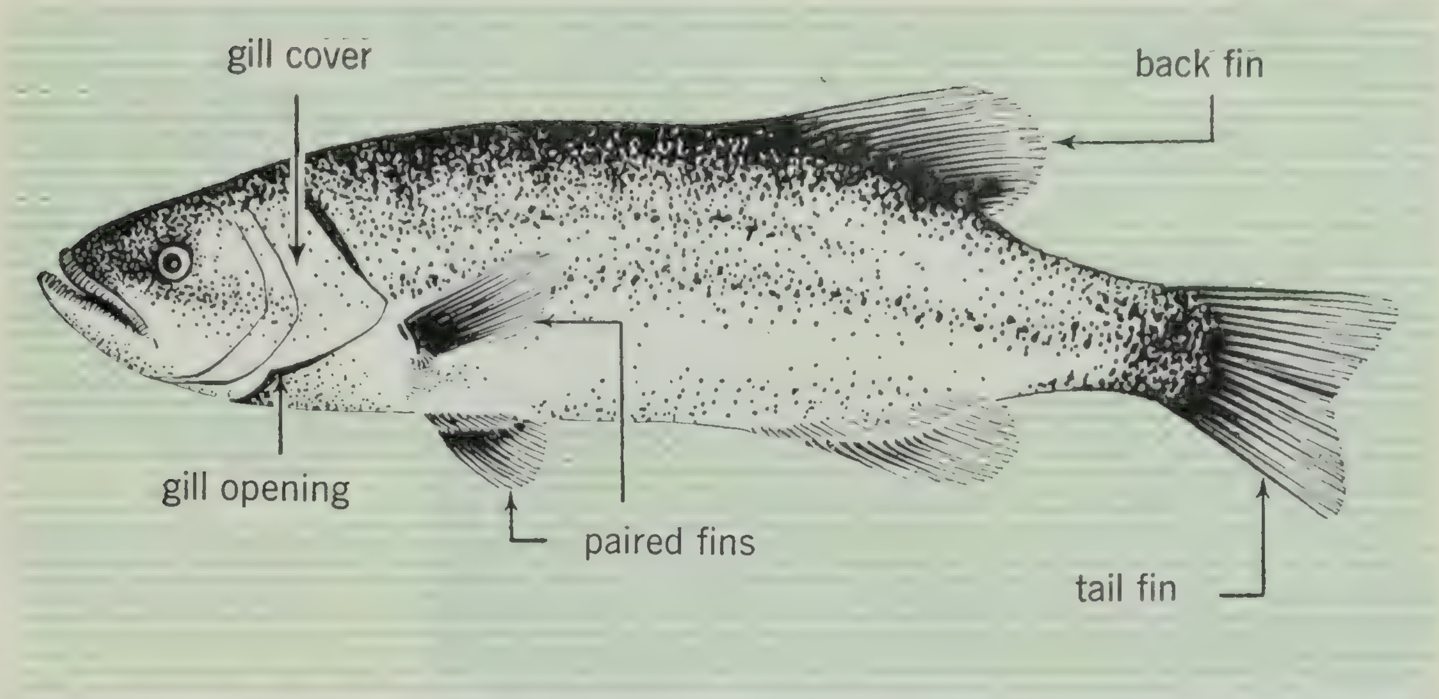
1. Observe a fish as it swims about in your aquarium or in a pond, lake, or stream. Describe and draw its shape. How does its wedge shape help it to move? How does man make use of similar streamlining to improve travel in air and in water?

2. Most fish, but not all, have scales. Study the arrangement of the scales. How does their overlapping aid movement through the water?

3. Observe the fins. Notice the two pairs of side fins. How do their positions compare with the positions of the front and hind legs of mammals? Notice that the fins contain a framework of *fin rays.* By watching a fish swim, try to find out the uses of (1) the paired fins, (2) the single fins along its back and underline, and (3) the strong tail fin. Which ones are used for moving forward and backward, stopping, and balancing?

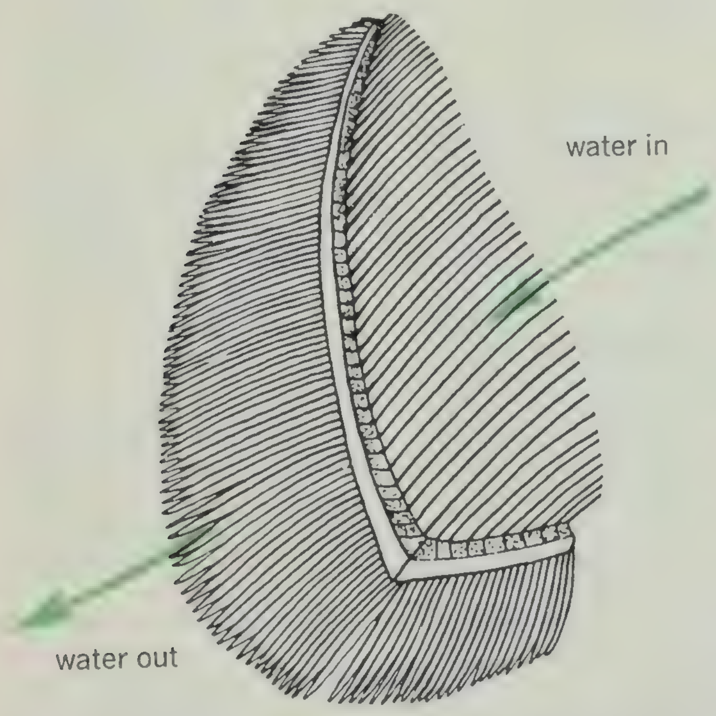
4. Study the *gills* of a large, freshly killed fish. Lift up the *gill cover* and examine the gills. How many are there? Find the bony J-shaped *arch,* from the outside of which project many soft, fleshy *filaments,* or threads, and from the inside, a number of short, spiny *rakers.* Notice how red the filaments are. Open the mouth of the fish, and notice the passageway between the mouth and the gill opening. What purpose does it serve? Watch a live fish in your aquarium to see the two following movements: (1) the opening and closing of the mouth, and (2) the opening and closing of the gill covers. Notice that the gill covers open slightly after the mouth.

The purpose of the gills is to enable fish to breathe under water. When the mouth of the fish is opened and then closed, water enters, and is forced out over the gills and through the gill opening. Oxygen in the water passes into the blood flowing through the thin-walled filaments. At the same time, carbon dioxide passes out of the filaments into the water. Thus the blood is purified by losing its wastes and taking on a fresh supply of oxygen. The oxygen is carried by the blood to the cells, where it is used



A fish, showing the fins and other external parts. Find them on a fish of your own. How is each fin useful?

in respiration. The heart of a fish is composed of two chambers only; the heart of a mammal has four chambers.



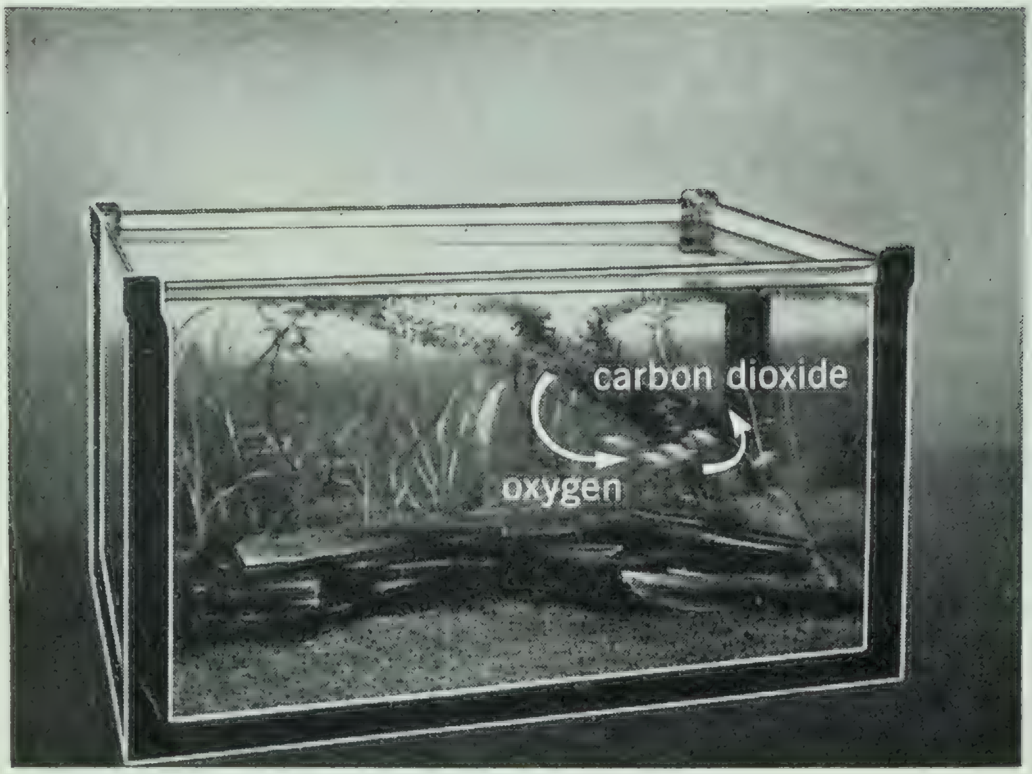
Gills of a fish. Observe the gill rakers, the gill arch, and the gill filaments in each case. The arrows show the direction in which the water flows. What happens as the water flows through the gill rakers? What takes place as the water passes through the filaments?

Setting up a classroom aquarium

An aquarium, carefully set up and cared for, is "a pond in a glass box," because it provides a habitat for fish and plants very much like their natural home. An aquarium is not only attractive and interesting, but it also gives us an opportunity to study the adaptations of fish, and helps us understand how animals and plants depend on each other.

SOMETHING TO DO

1. Make a field trip to a pond or stream to gather materials for setting up an aquarium. Take along a net and several jars or pails. Bring back a pailful of coarse, carefully washed sand, various plants found growing in the water, a few snails, a clam, a *few* small minnows, and a pailful of clean pond water. Plan to have only about one or two inches of fish to each gallon of water in your aquarium.



A classroom aquarium, showing how the oxygen cycle operates. Oxygen given off by the plants is taken into the gills of the fish, and the carbon dioxide given off by the fish is used by the plants. (Courtesy General Biological Supply House, Chicago)

Note: After you have set up an aquarium, be sure that you do not neglect the animals in it!

2. When you return to school, set up your aquarium as follows: (1) Clean the container thoroughly. (2) Cover the bottom with 1 to 2 inches of clean sand. (3) Cover the sand with a sheet of paper and carefully pour in the water. Then remove the paper. (4) Arrange a few rooted water plants in the back corners, and let a few others float in the water. (5) Let the aquarium stand for a day. Place it near a north window, or well back from another window, so that it receives very little *direct* sunlight. Excess light causes tiny plants called *algae* to multiply rapidly, turning the water green. (6) Put a metal or glass lid on the aquarium to reduce evaporation and keep out dust. (7) After a day or two, add the water animals. (8) Feed your fish sparingly; a pinch of fish food daily is enough. If there are a number of snails in the aquarium, they will help to clean up any food not eaten by the fish.

If you have set up your aquarium in this way, the plants will give off enough oxygen for the fish, and use up the carbon dioxide, breathed out by the fish. If your fish gasp at the surface, there may be several explanations. There may be too many fish or too few plants, you may be overfeeding the fish, or the aquarium may need more light.

An aquarium seldom needs to be cleaned out, as the snails and plants use up most of the waste material.

Amphibians

One of the early signs of spring is the chorus of mating calls made by *frogs* and *toads*. Shortly after the ice disappears, these amphibians lay their jelly-like masses and strands of eggs near the surface of the pond.

The word *amphibian* means "double life." Most animals in this group start life in the water, usually as tadpoles. At this stage they take in oxygen by means of the gills. Their food is the

Two common amphibians are the green frog (left) and the common toad (right). The former is an excellent example of an animal with protective coloration; the latter is a very useful animal to have in a garden. Why should frogs and toads be protected?

thousands of tiny water plants and protozoans in water. Later, most amphibians spend all or part of their lives on land, where they breathe through their skins or by means of lungs. They eat small animals, such as insects, crustaceans, and protozoans.

SOMETHING TO DO

1. Bring to school a *few* frogs' or toads' eggs and keep them in a jar of pond water. Frogs' eggs are found in a mass, while toads' eggs are laid in strands (see diagram on page 60). Place the container in moderate light, and from

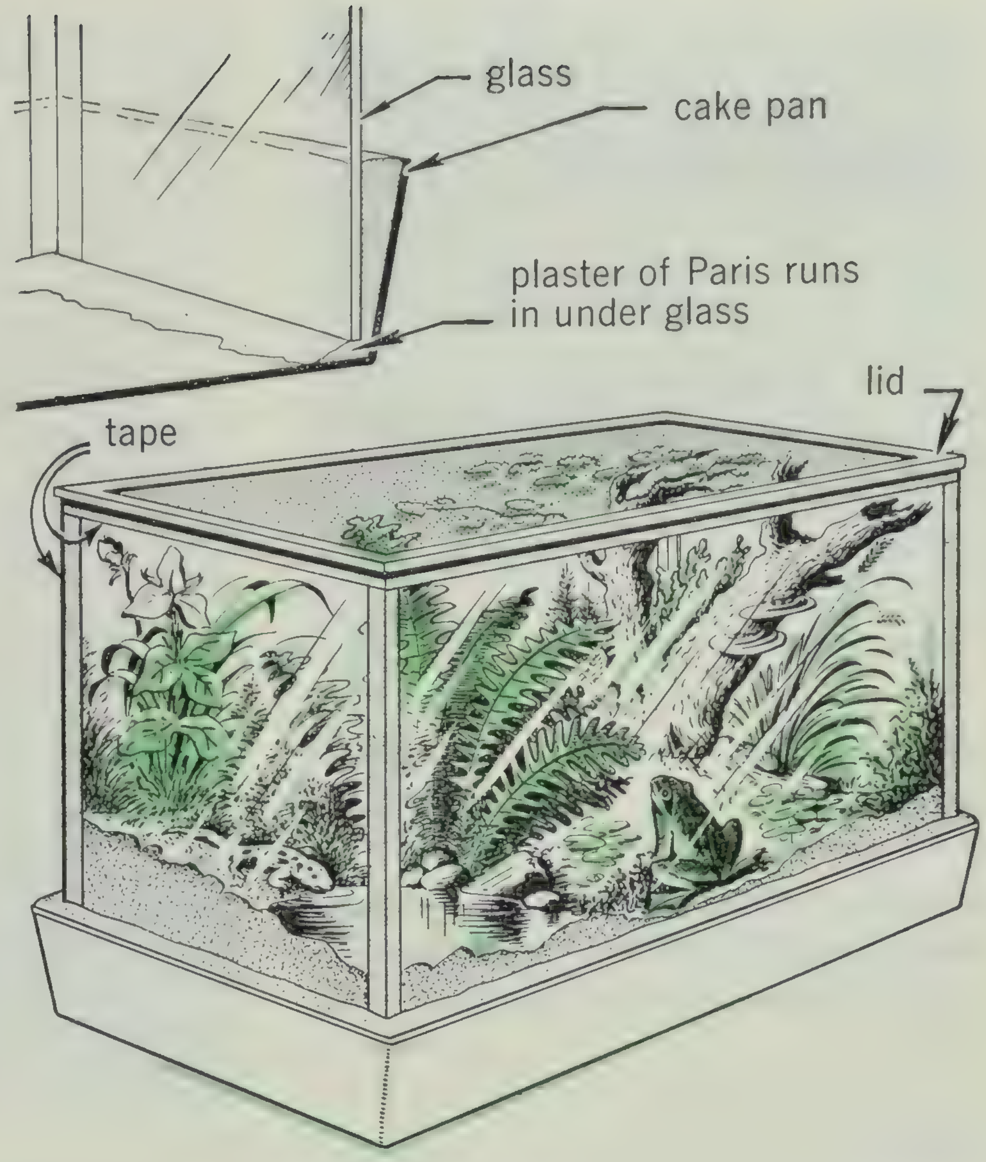
The horned toad, or more correctly the horned lizard (a reptile), is found in areas where dry, semi-desert conditions prevail. Its wide, flat body is covered with fine scales with a row of spines along each side. Its color is brownish-grey above and light below. The head has rows of horns. On hot days the horned toad is quick and active. Its food is mainly insects. Its young are born alive. The horned toad protects itself by swelling up its body, opening its mouth, and giving out a hissing sound. Under extreme irritation it expels a thin stream of blood from its eyes. (Richard Fyfe photo)

day to day observe the changes that take place. Watch for the appearance and growth of the black spot in each fertile egg. After the eggs have hatched, look for the tiny *tadpoles* attached to a stick or to the side of the container. Can you see the tiny feathery *external gills* that are used in taking oxygen from the water? Examine the tadpoles after a few days, when they become active. Can you locate the *internal gills* that have replaced the external ones? What do the tadpoles eat? You might add *tiny* pieces of lettuce to their usual diet of algae. Add a few snails to help keep the water clean.

Watch the tadpoles for the appearance of hind legs, and later, of front legs. Notice that the tail becomes shorter. What actions indicate that the tadpole is beginning to breathe with nostrils? Soon the developing frog or toad will climb on to a stick placed on the water. Its gills will now be entirely replaced by lungs. Keep one or two of the animals, and return the rest to the pond.

2. Make a *terrarium* like the one shown on page 61 as the home for a small frog, a toad, and perhaps a salamander. A terrarium for such animals should contain a saucer of water. Feed the animals flies, grasshoppers, and earthworms. If you feed them with a pair of tweezers made of two strips of wood, you can train them to eat bits of raw meat. *Keep your terrarium clean and moist at all times.*

Stages in the life-history of a frog. Top: A frog's eggs are shown at the left and a toad's eggs at the right. How are they different? Through the magnifying glass we can see changes in the developing eggs. The newly-hatched tadpoles cling to water plants. Notice their external gills. Soon these are replaced by internal gills, and the tadpole begins to swim about in the water. Study the changes in the growing tadpoles. Which legs appear first? The tail is gradually absorbed into the young frog's body. When their internal gills are replaced by nostrils and lungs, frogs are able to come out on land.



This ıerrarium was made of a cake pan, five pieces of glass, a pound of plaster of Paris, and a roll of adhesive tape. The plaster of Paris is mixed with water to fill the space between the pan and the glass. Put an inch of coarse sand and a few pieces of charcoal on the bottom and add an inch of soil from the woods. Plant mosses, ferns, and other plants from the woods. Keep the terrarium fairly moist, and keep it away from direct sunlight.

Be sure to keep your terrarium clean.

3. Study a frog and a toad to find out how they are different. How do their skins and colors differ? Do they catch their food in the same way?
4. Observe how frogs travel on land and in the water. How are they adapted for jumping, swimming, and hiding? Are their skins slippery? How is this an advantage?

It is fortunate for frogs that they have such adaptations as a slippery skin, strong legs for jumping, and a protective coloring, for they have many hungry enemies.

Frogs and toads are friends of the farmer and gardener. They have enormous appetites, which they satisfy by catching numerous flies, grasshoppers, beetles, cutworms, and other insect pests. On one occasion a scientist examined the stomach of a toad that had been accidentally killed. He found that it contained 30 cutworms, all eaten during the previous night. He estimated that a toad is worth at least $10.00 a year to the gardener. By protecting the frogs and toads of our fields and gardens, we shall be guarding our crops against insect foes.

Amphibians have no scales; most of them have smooth, moist skins. This is one characteristic that distinguishes

Two land amphibians are (top) the tiger salamander and (bottom) the spotted newt.

them from lizards. Lizards are reptiles and therefore have scaly skins.

Newts and *salamanders* are also amphibians. Scientists believe that the early amphibians were the first vertebrate animals to be able to live on land.

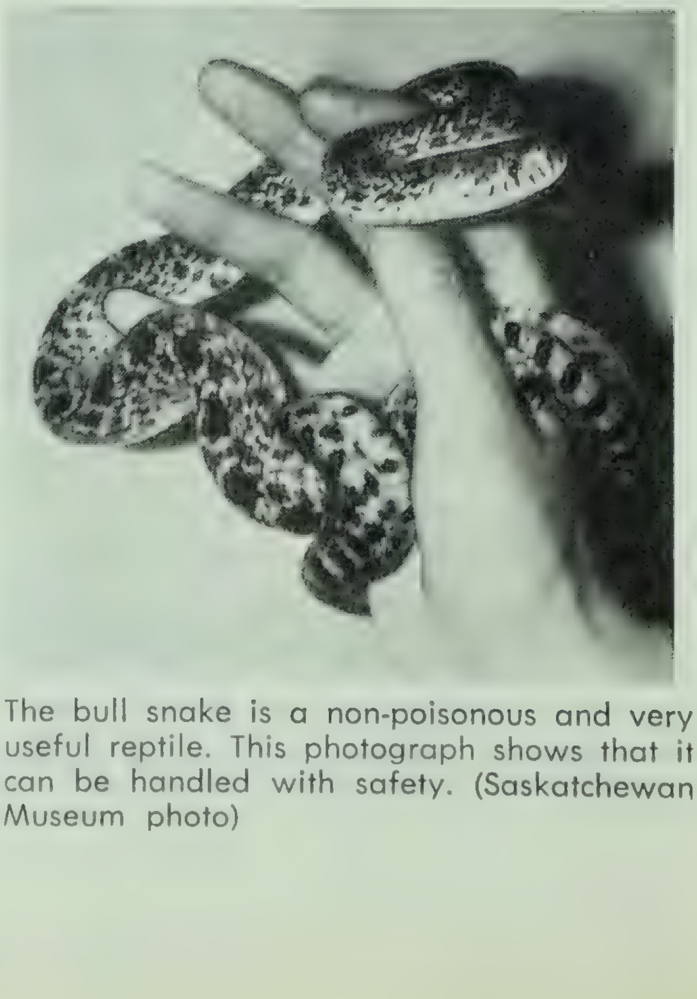
Reptiles

It may seem strange to include *snakes, lizards, alligators, crocodiles,* and *turtles* in one group. Nevertheless, they are all classed as reptiles. These animals are covered with thick scales, or plates. Those with legs have hard claws. Some reptiles, particularly lizards, are much like adult amphibians. However, there are two chief differences: (1) With few exceptions, reptiles, as you have learned, are covered with scales, while amphibians have smooth skins. (2) Reptiles breathe by means of lungs throughout their lives, whereas young amphibians and some adults have gills which enable them to breathe in the water.

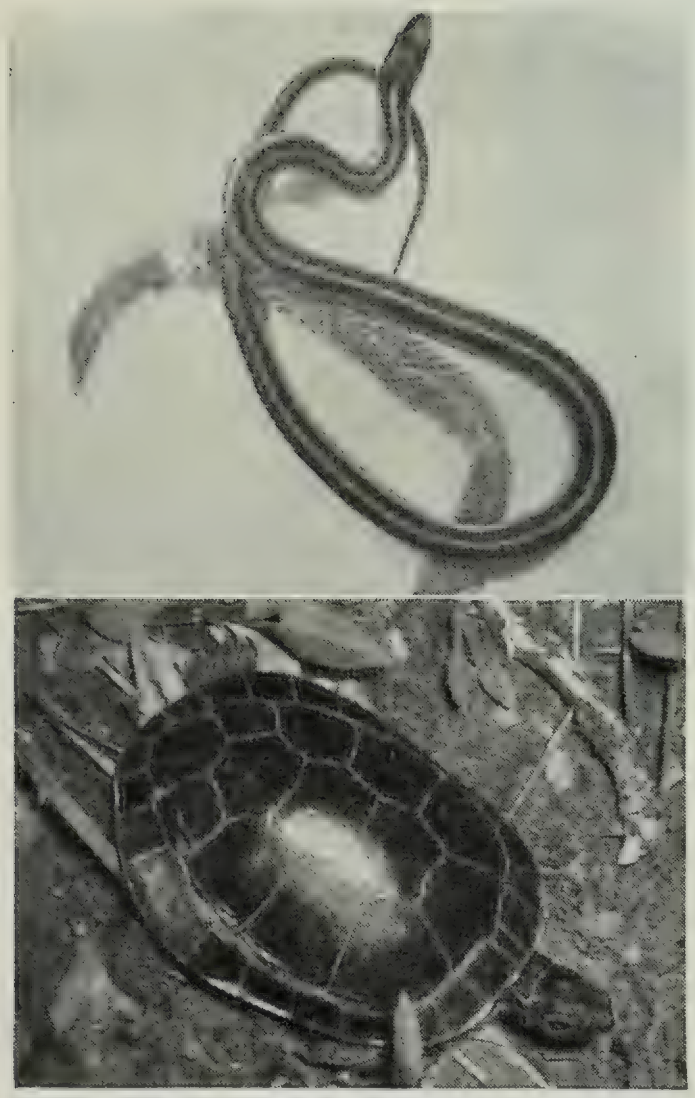
Most reptiles lay eggs, but a few snakes, including the garter snake, retain their eggs in their bodies until they hatch. The young are thus born alive. The eggs of most reptiles can be distinguished from birds' eggs by their leathery shells. Their eggs, too, are different from the eggs of amphibians, which have no hard covering.

Snakes have no legs. They feed chiefly on live animals. Their jaws are so constructed that they can be opened very widely, thus enabling snakes to swallow animals with bodies thicker through than their own bodies. Several kinds of *rattlesnakes* are the only poisonous snakes in Canada. Rattlesnakes are found in only a few parts of our country.

The common *garter snake,* like most snakes, feeds chiefly on insects and other small animals that become too



The bull snake is a non-poisonous and very useful reptile. This photograph shows that it can be handled with safety. (Saskatchewan Museum photo)



Two common reptiles are (top) a garter snake, which has just shed its skin and (bottom) a painted turtle. In what ways are these animals similar? (Top, Ken Nicholls photo; bottom, Ontario Department of Lands and Forests photo)

numerous. Thus it deserves our protection. The food of the *bull snake*, which may become quite large, is mostly gophers, rats, mice, rabbits, and eggs. It has been estimated that a bull snake is worth $15.00 to a farmer. It is another snake that deserves to be protected.

Turtles can readily be identified by their thick shells. They feed upon both plants and animals. *Crocodiles* and *alligators* are the largest reptiles of today. They are found only in warm regions. *Lizards* are small reptiles. Their food is chiefly insects. One hundred million years ago reptiles were very common. Among them were the dinosaurs of which only fossils remain today. One of the dinosaurs was the largest land animal that ever lived.

In addition to their usefulness as destroyers of harmful insects, some reptiles have other values. Leather is obtained from snakes and alligators. Some large turtles are used for food.

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. What is the distinguishing characteristic of all vertebrates?
2. Name and give examples of the five groups of vertebrates.
3. State at least two reasons why fish are said to be the lowest group among the vertebrates, and mammals the highest.
4. Describe the adaptations of fish for life in the water. Refer to shape, scales, fins, breathing, securing food, and escaping enemies.
5. Why are plants necessary in an aquarium? When is an aquarium balanced?
6. What characteristics of amphibians suggest that they were the first vertebrates to leave the water to live on land?
7. Why should frogs and toads be protected?

8. Describe the ways in which a frog (or toad) is fitted to survive. How does a frog develop from an egg to an adult?

9. How can you tell an amphibian from a reptile? In your answer include the names of at least two animals in each of these groups.

10. Using the garter snake and the bull snake as examples, discuss the value of snakes as friends of the farmer and gardener.

BIRDS

Birds comprise the fourth group of vertebrates. Because there are many kinds of birds, and because most birds are useful to man, we shall devote a full section of our chapter to the study of them.

Birds — the air force

Birds are the world's best aviators. Without the benefit of runways they take off and land in all kinds of weather. Gulls and hawks can glide for hours on the winds, seldom needing to beat their wings. The helicopter of the bird world, the tiny hummingbird, can even fly backward.

As you have observed, *birds* are the only animals with feathers. All of them have hard bills or beaks, and two legs. Every kind of bird hatches from hard-shelled eggs.

Birds are also well adapted for securing food. Seed-eaters, such as goldfinches and grosbeaks, have short, thick bills suited for cracking seeds. How are the curved beaks and claws of hawks and owls adapted for obtaining food? What special adaptations have woodpeckers? How can you identify swimming birds? Why do marsh birds such as herons, cranes, and bitterns have long legs, necks, and bills? Birds have no teeth. Instead, they have a gizzard in which their food is ground up. The body temperature of some kinds of birds is as high as 112°F. Consequently, they "burn up" a great deal of food and spend a large part of their time searching for new supplies. Some kinds of birds eat nearly their own weight of food each day.

Only mammals and birds are *warm-blooded.* Their body temperature remains nearly constant, and most of them are active in winter as well as in summer. All other groups of animals are *cold-blooded.* Their body temperatures go up or down, depending on the temperature of their surroundings. They are active only when the weather is warm. During periods of cold, they become less and less active.

Adaptations for flight

Birds accomplish flight by pressing down on the air with their wings. The wings, feathers, and bones of birds are specially adapted for flying.

A yellow warbler carrying an insect to its young in the nest. This picture shows an animal and a plant. How are both alike? Compare the movement of which the animal and the plant are capable. In what respects are the plant and the animal different? (Hugh Halliday photo)

SOMETHING TO DO

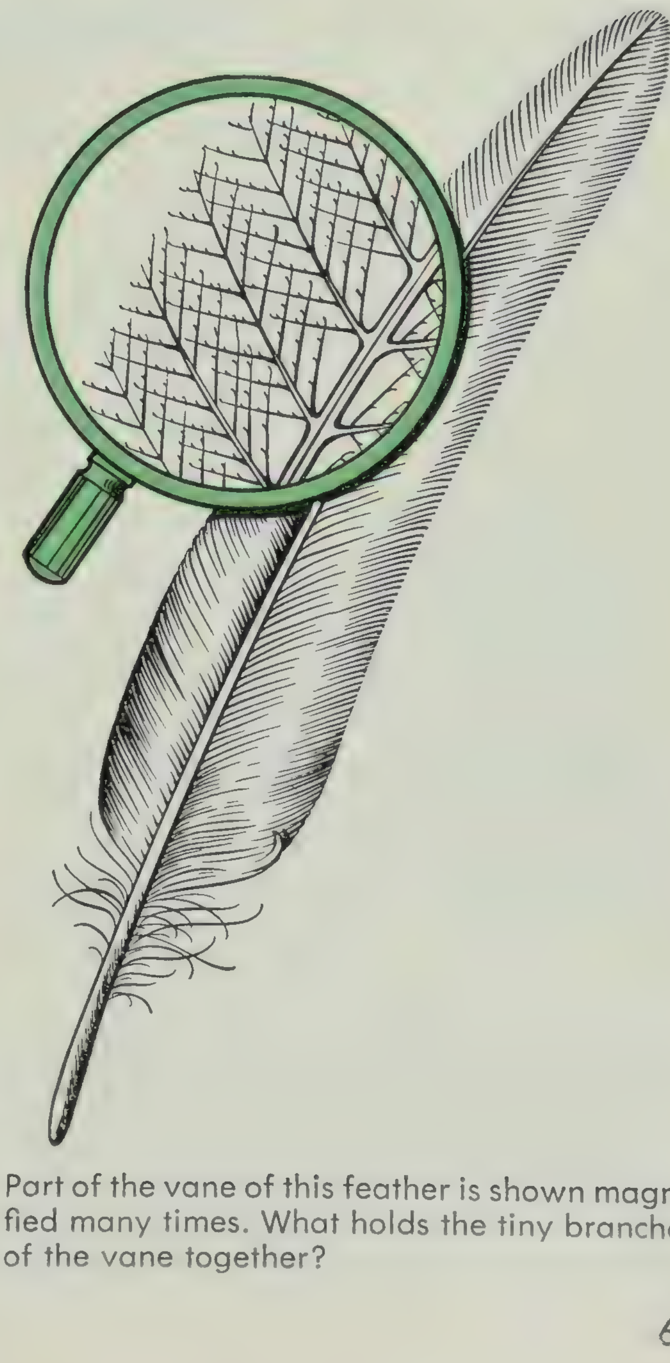
1. Examine the wing of a hen. Compare it with your arm. Find parts similar to your upper arm, forearm, and hand. Is the wing slightly curved underneath? What purpose does this serve? Why do the feathers overlap?

2. Examine a large feather. Find the broad *vane* and the hard *shaft*. What is the use of each? Notice that the larger part of the shaft is hollow. How does this affect its weight? Through a magnifying glass, examine the thread-like branches of the vane. Run part of the vane through your fingers. Do the tiny hooks separate and then interlock again? What purpose do the hooks serve?

3. Consider the value of the bird's tail feathers for steering and for braking when it lands.

4. Observe birds in flight to answer the following questions: Which birds travel faster, those with long wings or those with short wings? Which beat their wings more rapidly? Which can make faster take-offs? Which can glide better?

5. Observe various birds to find out how their shapes are adapted for flight.



Part of the vane of this feather is shown magnified many times. What holds the tiny branches of the vane together?

This map shows the four main flyways followed by migratory birds. The locations of winter resting grounds of many common migrants are also shown by means of arrows. The metal band shown in the upper corner is used to solve some of the mysteries of migration. Birds are caught in nets, banded, and released unharmed. When a banded bird is found, the band should be sent to the address shown, along with information about the date and place where the bird was found. This information helps scientists to learn about migration routes, the rates of speed at which birds migrate, and other facts.

The wonder of bird migration

For centuries people have been interested in the migration of birds. In early times there were strange tales to account for the disappearance of so many birds each fall. Today we know that numerous birds, from the great hawks to the tiny humming-birds, once a year make the long journey back and forth between a summer home in the north and a winter home in the south.

Not all birds migrate, but as fall approaches, millions of birds in all northern areas begin preparations for their southward migration. What prompts them to go? Cold weather does not seem to be the only factor, because many birds remain all winter. Perhaps a decreasing number of insects causes a food shortage among insect-eating birds. Possibly seed-eating birds find that shortening days do not give them sufficient time to gather all the food they need. Other reasons have been advanced to explain why birds migrate northward and southward. However, you can see that a great deal remains to be learned. Scientists have not fully solved the mystery of the great annual migration of our bird population.

Where Do Birds Go? — Some birds, such as barn swallows, nighthawks, and warblers go south to areas in Central and South America. The Arctic tern crosses Newfoundland and the Atlantic Ocean, then turns south along the coast of Europe and Africa, and finally travels straight down the middle of the south Atlantic to Antarctica. The ruddy turnstone travels from Alaska to Hawaii in a non-stop flight. The golden plover flies from Canada to South America across 8000 miles of ocean with only occasional rests on the water. Other birds, however, such as robins, wrens, juncos, and meadowlarks, move only a few hundred miles southward. The snowy owl moves southward from the Arctic only when food is scarce. Consult the map on page 66 to learn more about summer and winter homes and the routes followed by the birds as they journey north and south.

SOMETHING TO DO

1. Watch for fall changes in the plumage of birds. Try to recognize your summer bird friends in their fall color markings. What advantage is it for birds, both male and female, to be dressed in dull shades for their migration travels?
2. Watch flocks of birds during practice flights. Is there a leader?
3. What birds gather in flocks in the fall? House sparrows assemble in small flocks each autumn, but do not migrate. What might this indicate?
4. Prepare maps to show the summer and winter homes of birds that you know. Use different markings for summer and winter locations. Show the *flyways* followed by the birds.
5. In early spring, make a bird calendar showing the date when each migratory bird returns to your district. Keep your records from year to year to compare the dates on which each kind of bird is first seen. Be as accurate as you possibly can.

See how many sparrows you can identify this spring and summer. The sparrow family is a large one and includes many attractively colored and useful members. Many, too, such as the white - throated sparrow shown in this illustration are among the sweetest singers of all our birds. Use a bird book to identify as many sparrows as you can. (Fred Lahrman photo)

How Do Birds Find Their Way?— The answer to this question has been one of the mysteries of bird migration. While larger birds, such as waterfowl and shorebirds, travel by day, small land birds journey by night. In some cases young birds and old birds migrate at different times and by different routes. Long flights over water are marked by few, if any, direction guides. How do the birds keep on the right path? It has been thought that birds have a *sense of direction* that guides them to their destinations. More recently, it has been suggested that the magnetism of the earth and the force of the earth turning on its axis exert influences that in some way keep migrating birds going in the right direction.

The Dangers of Migration. — Birds frequently undergo many hardships, and a great many lose their lives during migration. Large numbers are dashed to their deaths against tall buildings, bridges, and telephone wires. Changes in the weather and sudden storms drive many birds far off their courses. Food may be covered by blankets of snow. Hunters and natural enemies lie in wait for birds as they stop to rest and feed.

Food and value of birds

Consult pages 116 to 122 for information regarding weed seeds, rats and mice, and insect pests eaten by hungry birds. Anything that we can do to supply food and protection to birds during migration and other times will help to maintain our bird population and ensure their important contribution toward keeping weed, rodent, and insect pests under control.

A great many people do not know the truth about the value of birds of prey — the hawks and owls. Study the chart on page 119. Almost all our birds of prey are decidedly beneficial.

Most boys and girls have seen flocks of Canada geese swinging northward in the spring in their distinctive V-shaped formation. Here we see two adults in the northern end of their journey, with their family of three goslings. The black neck and white throat are distinctive markings of the Canada goose. (Ontario Department of Lands and Forests photo)

Be sure that you have the *facts* about these useful birds.

Hints on observing birds

Many good bird books have guides to help you in identifying birds that you do not recognize. To help in identifying a bird, you should make the following observations: (1) where seen; (2) size – compare with an English sparrow (small), robin (medium), or crow (large); (3) colors and markings; (4) movements and manner of flying; (5) song or call; (6) whether alone or in a flock; (7) outstanding characteristics, such as an unusual shape, the presence of a crest, the length and shape of the bill and tail, the length of the neck and legs, etc.

SOMETHING TO DO

1. Find in the photograph of a cedar waxwing on page 71 some of the following characteristics: Usually seen in small trees; nests in trees, such as hawthorns. About the size of an English sparrow. Light brownish-fawn on back, fading to slate-grey on head and breast; dark bar through eye; tail tipped with yellow; small red tips, like bits of sealing wax, on secondary wing feathers; primary wing feathers darker. Prominent crest. Often travels in flocks. Call – a sharp, fine *tse-tse-tse*.

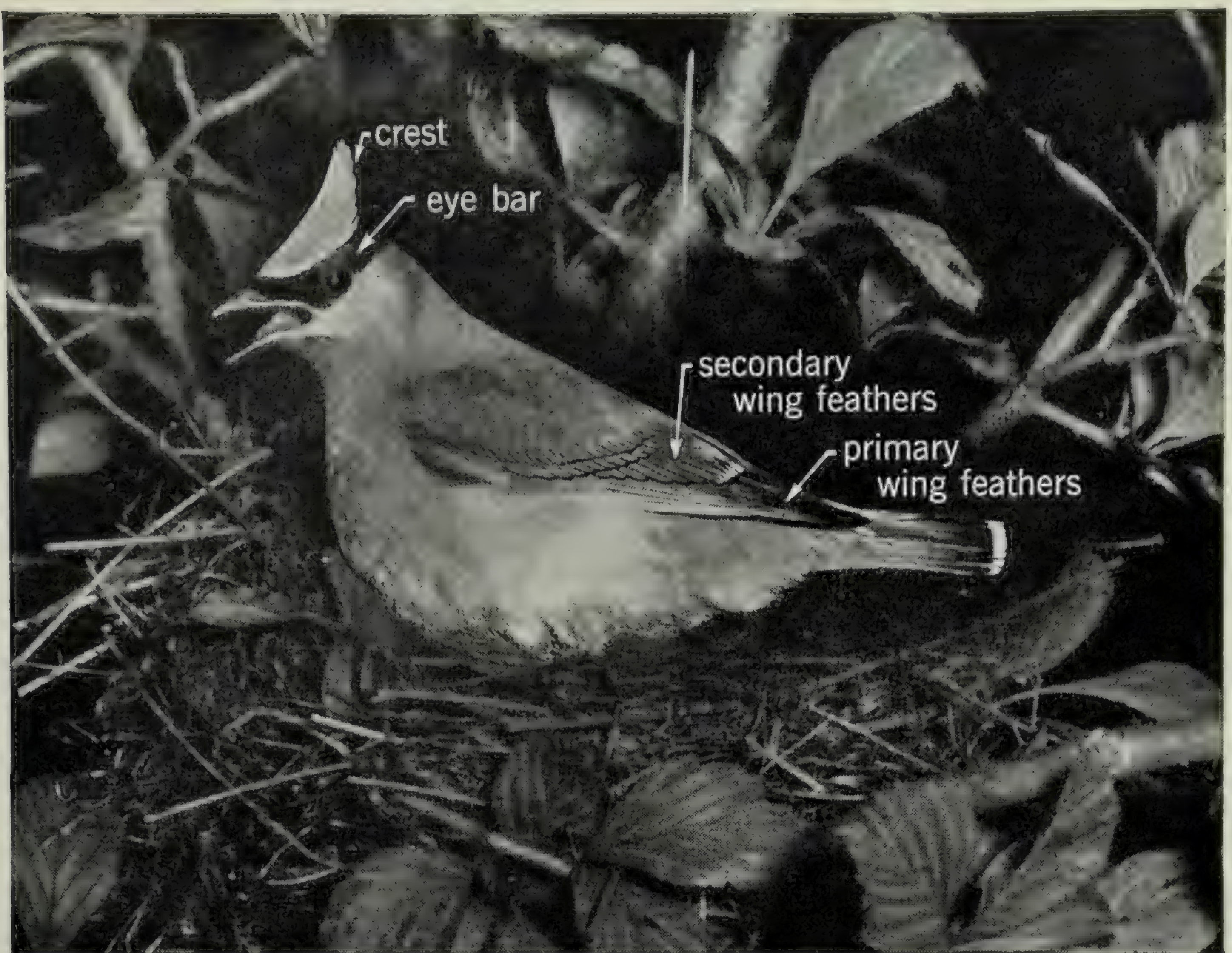
2. Plan trips for the purpose of studying birds: (1) Learn to recognize common birds by name. (2) Watch a kingbird or other insect-eating bird. Notice its method of capturing insects, where it perches, and the size and shape of its bill. (3) Observe the size and shape of the bills of weed-seed eaters. (4) Watch robins locating worms and pulling them out of the soil in the lawn. (5) Observe shore birds, such as the killdeer, the spotted sandpiper, and the marbled godwit, as they feed along the margins of lakes or streams. Find how the beak, the legs, and the feet are adapted to meet the needs of each bird. (6) Study such water birds as ducks (the mallard, the canvas-back, etc.), coots or mud hens, grebes, and others. Which are the best divers? Upon what do they feed? How are they adapted for swimming?

If you have never gone out early in the morning to listen and watch for birds, you have missed an experience that is very worth-while. Early morning is one of the best times to observe birds, because they are hungry and will be

very active as they look for their breakfasts. Go out by yourself or with a companion to the woods or open fields. If possible, take a pair of field glasses with you. Move quietly. Keep your eyes and ears open. You will be thrilled by the birds that you see and the nests that you may discover.

3. Learn to recognize birds by their songs and calls. Find out if your public library has a phonograph record of bird songs that you may play for your class.

Birds that you should know: (top, left to right) Pileated woodpecker; snowy owl, phoebe: (centre, left to right) kingbird; horned lark; American bittern: (bottom, left to right) song sparrow; olive- backed thrush; snow bunting. All these birds are useful and should be protected. (Hugh Halliday photos)



A cedar waxwing on its nest in a hawthorn tree. Some important means of identifying birds are shown. (Hugh Halliday photo)

These five young migrant shrikes left their nest only a few hours before this photograph was taken. (Hugh Halliday photo)

The mallard is our best known wild duck. It feeds at the surface of the water. Notice its broad, flat bill. (Ontario Department of Lands and Forests photo)

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. What two groups of animals are warm-blooded? Compare cold-blooded and warm-blooded animals with respect to body temperature and winter activities.
2. Explain how birds are adapted for flight. Briefly describe a feather.
3. Birds show many variations with respect to their adaptations for securing food. Name some birds with special adaptations and briefly describe their adaptations.
4. Describe the migration of birds, using the following headings: (1) Reason for migration, (2) Destination, (3) How they find their way, (4) Chief flyways, (5) Dangers encountered.

MAMMALS

Mammals, the group of animals to which man belongs, comprise the highest form of animal life. The brain development of mammals exceeds that of all other animals. It is therefore fitting that we should devote an entire section of this chapter to a study of mammals.

Some 4000 kinds of mammals have been identified. They vary in size from the tiny 3-inch long shrew to the 90-foot long, 120-ton whale, the largest animal that has ever lived.

The members of this group have hair or fur on part or all of their bodies. The name *mammal* comes from the fact that the females have *milk* or *mammary glands* that produce milk to feed their young. Mammals have a *diaphragm*, or breathing muscle,

dividing the inside of their bodies into two parts. One part contains the heart and lungs; the other, the stomach and other digestive organs. The diaphragm, by moving up and down, helps to empty and fill the lungs. Because such animals as the whale, seal, bat, kangaroo, and humans all have these characteristics, they are classed as mammals, even though they seem to be very different from such common mammals as dogs, cats, deer, horses, and hares.

You will recall that mammals are warm-blooded animals. How do warm-blooded animals differ from cold-blooded animals? Because their temperature remains nearly constant, most mammals remain active all winter. However, some mammals, such as bats, gophers, groundhogs, marmots, chipmunks, and a few others, hibernate during the winter. During hibernation their body temperature falls to about the same temperature as their surroundings.

The body activities of mammals are carried on by highly developed organs. Their hearts have four chambers. Their teeth are held in sockets and are a marked advance over the teeth of fish, amphibians, and reptiles. All North American mammals are born alive. Two mammals, the duckbill and spiny ant-eater found only in Australia, lay eggs. After the eggs hatch, the young are fed with milk. One group of mammals, known as pouched animals, give birth to very small and helpless young. Soon after birth, the young of these animals crawl into a pouch on their mother's body where they remain until they are large enough and strong enough to leave. Two pouched mammals are the kangaroo of Australia and the opossum of America. Bats are the only mammals capable of true flight.

The skull of a beaver showing its remarkable front teeth. How are the front teeth of rodents kept sharp for gnawing? (Charles Macnamara photo)

How mammals are adapted to survive

As you know, every animal must be able to find food, and to elude other animals that seek it for food. In general, mammals are well *adapted* for their way of living. Dogs and wolves, for example, have strong legs that enable them to catch other animals for food. Their keen sense of smell helps them seek out their food. Their strong, sharp teeth are adapted for tearing raw meat, and also serve as weapons of defence.

SOMETHING TO DO

1. Observe the special adaptations of a cat. What use is made of the soft foot

pads and the sharp claws? Compare the feet of a cat with those of a dog. Notice that the cat can withdraw its claws. How is this adaptation useful? Observe the pupils of a cat's eyes in daylight and in a nearly dark room. Why is it essential that a cat have eyes that make use of small amounts of light?

Observe the teeth of a dog or cat. Find the *incisors*, or front teeth; the *canines* long and sharp); and the *molars* (sharp-edged back teeth).

2. Discuss the adaptations of a horse. What purposes are served by the hoofs? Why did nature give the young colt legs that are almost as long as those of its parents? Compare the hoofs of horses and cattle.

3. Study other mammals, both domestic and wild, to see how they are adapted to help them find food and escape their enemies.

The beaver — a mammal well adapted for its way of life

Canada's national animal, the industrious beaver, has several adaptations for living in water. Its sharp, chisel-shaped teeth enable it to cut down trees, the branches of which it uses for food and as building material for the dam and the lodge. The front feet of this animal serve almost as hands to carry mud and handle tree branches. The powerful hind feet propel the beaver through the water. The broad, flat tail serves as a rudder when the beaver is swimming. By slapping its tail on the surface of the water, the beaver gives warning of approaching danger. The remarkable adaptations of this interesting animal serve it in obtaining food,

Beavers at home. Find the dam, pond, lodge, and other evidences of beavers' activities. How are beavers adapted for their way of living? Why should beavers be conserved? (Saskatchewan Government photo)

constructing its home, and escaping its enemies.

Other interesting adaptations of mammals

Every mammal has one or more special adaptations. Some mammals use protective coloration to help them find their food and escape their enemies. Rabbits depend on their brown coats to help them remain unseen. The snowshoe rabbit, or varying hare, becomes white in winter, and is difficult to see against a background of snow. The polar bear, Arctic fox, and weasel (in winter) all depend on their white coats to keep them from being seen by the smaller animals that they use for food. The spots of the fawn serve to camouflage it against the mottled forest floor. No one who has smelled the unpleasant scent of the skunk is likely to overlook the unusual adaptation of this quiet, slow-moving mammal. The bat, the only flying mammal, has wings made of webs of skin stretched over its front legs that enable it to

Some well-adapted mammals. How do special adaptations help each of these mammals?

Although fairly common in wooded regions of Canada, the flying squirrel is seldom seen because it is active at night, gliding from tree to tree on the well-developed webs stretching from its front legs to its hind legs. (C. G. Hampson photo)

catch night-flying insects. The squirrel's long, sharp teeth help it to open nuts so that it can eat the tasty food inside, while its bushy tail serves to balance it as it jumps from branch to branch. The flying squirrel makes use of a loose fold of skin that stretches between its forelegs and hind legs as it sails from tree to tree; unlike the bat, this animal cannot fly. The tough snout of the pig, the giraffe's long neck, the elephant's flexible trunk and thick hide, the deer's horns, and the seal's flippers are all special adaptations that enable their owners to secure food or escape their enemies.

A common shrew, the tiniest mammal. (Saskatchewan Museum of Natural History, Richard Fyfe photo)

The whale's body and limbs are adapted and shaped for swimming. It needs to come to the surface of the water only to breathe.

What other adaptations of either wild or domesticated mammals have you observed?

Groups of mammals

Most mammals belong to one of the groups described in the sections that follow.

Insectivores

This group includes the *moles*, *shrews*, and *hedgehogs*. As their name suggests, the mammals in this group are insect-eaters. Moles have spade-like front feet for digging.

The tiny shrew is an interesting animal that is seldom seen. About 3 inches long, it is brown above and grey beneath. It looks like a tiny, slender, sharp-faced mouse. Its eyes are very small and its ears are almost hidden in its fur. The shrew does not burrow as the mole does. It is usually found in fields and woods where food is plentiful. Insects, worms, and other small animals form the chief food of the shrew, which eats over three times its own weight each day! The shrew is highly useful in our battle against harmful insects. Shrews are said to be very vicious and quarrelsome, in spite of their small size. However, one authority states that they are probably not as bad in this respect as some people believe them to be.

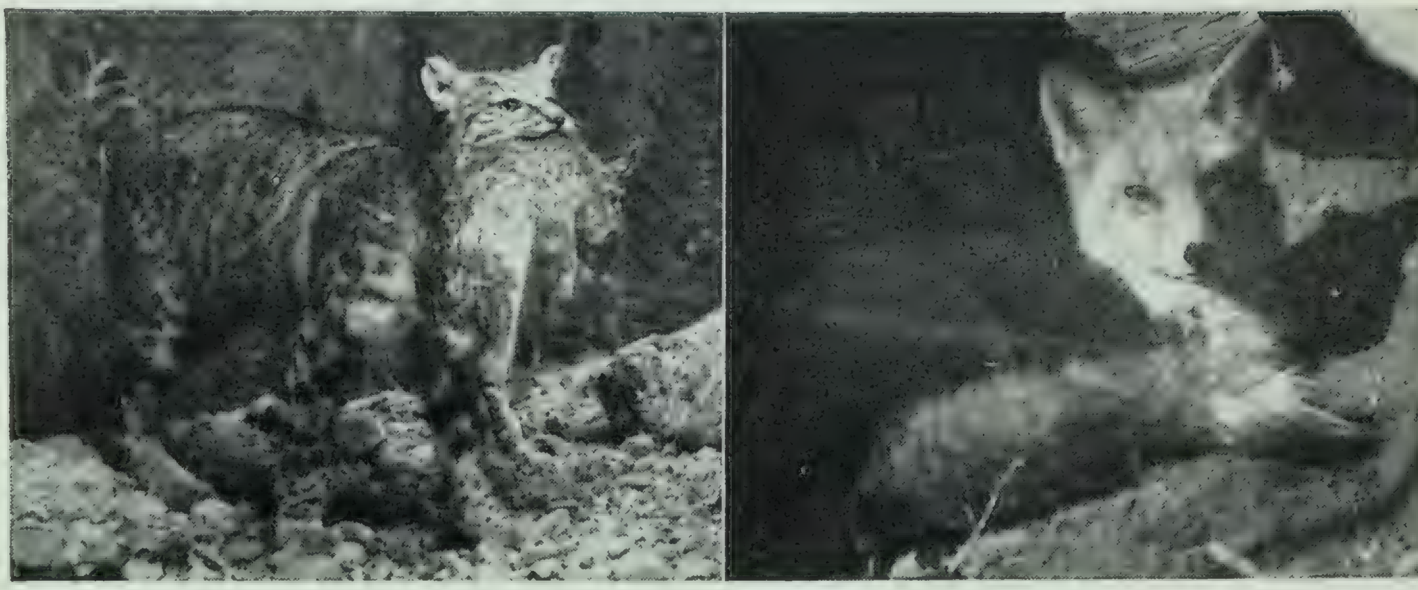
Bats

These are the only *flying mammals.* The wing of the bat consists of a thin skin or membrane stretched between greatly lengthened fingers and fastened along the sides of the body. Bats are found in houses or other buildings, and in caves. Their food consists entirely of insects caught at night when they are flying. During their graceful and rapid flight, bats avoid dashing into objects by an interesting method somewhat like radar. As they fly, they send out a very highly pitched sound. This sound is reflected from nearby objects and warns the bats of their presence. Bats are most active just after sunset and just before sunrise. During the day, and during hibernation, they hang head-down with their wings folded against their bodies.

Carnivores

These are the *flesh-eating animals.* No doubt you immediately think of lions, tigers, and other members of

How are bats adapted for flying? How does a bat avoid striking objects while in flight at night?



The lynx (left) and the red fox (right) are carnivores. The lynx is taking a captured hare to its den. The red fox lives mainly on field mice. What adaptations have the lynx and the fox which enable them to feed upon other animals? (Saskatchewan Government and Pennsylvania Game Commission photos)

the *cat family,* and wolves, coyotes, and others of the *dog family.* There is also a group of *water carnivores,* the seals and walruses. Other carnivores are *bears, racoons, mink, weasels,* and *skunks.* Most of these animals have strong, muscular limbs and bodies. Seals and walruses have short modified limbs or flippers for swimming, and teeth adapted for holding and piercing their food. It is interesting, too, to note that some carnivores walk flat on their feet (bear and racoon); others walk on their toes (dog, wolf, fox, cat, tiger, lion); still others walk partly on their toes (mink, weasel, skunk).

A few carnivores, such as the bear, walrus, and seal, are useful as food animals, but these carnivores contribute their greatest value to man as fur bearers. We get valuable fur from the fox, mink, otter, marten, fisher, seal, and others.

Rodents

These are the *gnawing animals.* The members of this group have greatly developed, chisel-shaped front teeth adapted for gnawing. These teeth keep on growing. The front edge is harder than the rear edge and wears away less rapidly. The gnawing teeth of rodents are therefore self-sharpening. The rodent group is large, including more than one-third of all mammals. Some members are rats, mice, groundhogs, gophers, ground squirrels, tree squirrels, muskrats, beavers, porcupines, guinea pigs, and others. Some of these rodents, such as the beaver, muskrat, and squirrel, are extremely valuable to man as fur bearers.

There are other rodents which cause much damage. The house rat, in particular, spreads disease, eats and spoils food, kills chickens and other small animals, eats eggs of both wild and

The muskrat is a water rodent. (Hugh Halliday photo)

The harmful house rat. (Fred Bard photo)

The pocket gopher is a true gopher. (Richard Fyfe photo)

Richardson's ground squirrel, commonly called the flickertail gopher.

domestic birds, and gnaws holes in wooden parts of buildings. The house mouse eats and spoils great amounts of food. Wild mice damage crops.

Rodents thrive and become numerous because: (1) they are comparatively small and quick; (2) they reproduce rapidly, many having several large families or litters per year; (3) they are hardy and adaptable to changing conditions.

An active young red squirrel.

Rabbits and hares

These animals have two very large upper incisors, or front teeth, and two smaller ones on the lower jaw. *Hares,* such as the varying hare, or "snowshoe rabbit," and the prairie hare, or "jack rabbit," do not dig or burrow, and bear well-developed young that are born well covered with fur and with their eyes open. *Rabbits,* such as the cottontail, bear helpless, naked young which remain blind for several days. Jack rabbits are grey in summer, and the varying hare is reddish-brown. Both are white in winter. Jack rabbits can run at speeds up to 30 miles

The prairie hare, or jack rabbit, dressed for winter. Why is white a good color for animals that are active at this time of year?

These young cottontail rabbits are just seven days old. They were born naked, and will not have their eyes open for several more days. How are hares different from rabbits? How are hares and rabbits alike? (Hugh Halliday photo)

or more per hour. In winter, the long, spreading toes of the varying hare are covered with a heavy coat of hair. This fits the animal with broad "snowshoes" for travelling freely over the snow. Cottontail rabbits are smaller than the hares just mentioned. One kind is plentiful in the brushy coulees of southern Alberta and Saskatchewan. Cottontails may inhabit badger holes, hollow logs, or natural crevices, or they may dig a hole for themselves under a rock.

Hoofed animals

You no doubt can list a large number of mammals with hoofs. They are an important group as far as man is concerned. Many provide us with milk and a large part of our meat supply. From some we secure hides for leather. Sheep and others are sources of wool and of other clothing needs. Their horns, hoofs, and bones are used for many purposes. Many, too, have helped man pull his farm implements, transport his goods, and perform other kinds of heavy work.

The Prairie Provinces are the home of a number of wild hoofed-animals. The bison, sometimes called buffalo, roamed the plains in great herds. White-tailed deer, mule deer, and wapiti (or elk) graze in wooded areas. The agile pronghorn antelope prefers the open prairie. Moose thrive in forested lake country all across Canada. In the far north the caribou may be seen. In the foothills and on the mountain slopes the bighorn sheep and mountain goat live safely.

All hoofed animals feed on plants. Their molar teeth are fitted for grinding. Most of them have a sideways jaw motion. Their legs in most cases are adapted for running swiftly. There are two main groups of hoofed animals:

1. Those that walk on one toe (single hoof): horse, rhinoceros.

A thoroughbred horse (left) and a whitetail deer (below). Both are hoofed animals. (Saskatchewan Department of Agriculture and Ontario Department of Lands and Forests photos)

How do the thoroughbred horse and the whitetail deer differ in respect to hoofs and method of eating? How are they alike? In what ways have hoofed animals been useful to man?

2. Those that walk on two toes (referred to as a split hoof). This group is further divided as follows: (1) *Ruminants,* or those that chew the cud. The cow, for example, first compresses its food into a ball which is swallowed and passed into the first division of its stomach where the food is stored. Later, food is forced back into the cow's mouth and thoroughly chewed. The food is then swallowed again and passes into the remaining divisions of the stomach where digestion takes place. This method of feeding has this advantage: a quantity of bulky food can be eaten quickly and stored to be chewed and digested later. Among the mammals that chew the cud are cattle, bison, deer, elk, moose, antelope, camels, and goats.

(2) *Non - ruminants:* pig, hippopotamus. You will learn more in Chapter 8 about several breeds of domestic hogs. As you probably know, pigs do not chew the cud as cattle and other ruminants do.

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. By what characteristics can we distinguish mammals from all other animals?
2. How is the beaver adapted for its way of life?
3. Mention one special adaptation of each of the following mammals: fawn, skunk, bat, kangaroo, giraffe, elephant, whale, shrew, seal.
4. Briefly describe the chief characteristics of the following groups of mammals: *carnivores, rodents,* and *hoofed animals.* In what ways are some of the members of each group harmful or useful to man?

Rocky Mountain sheep, such as these shown in Jasper National Park, are among the wild hoofed animals. (Canadian Government Travel Bureau photo)

The bison is another hoofed animal of Alberta.

WHAT HAVE YOU LEARNED?

IMPORTANT SCIENCE IDEAS AND UNDERSTANDINGS

A

1. All living things resemble each other in the following ways: their bodies are composed of cells; they require food and oxygen; they are capable of some movement; they grow and reproduce; they respond to sight, sound, and other messages from their environment.
2. All living things are either plants or animals.
3. Plants and animals are different in certain respects. Green plants manufacture food. Most animals can move from place to place.
4. There are two main groups of animals: invertebrates and vertebrates.
5. Both invertebrates and vertebrates are adapted to live in their environment.
6. The group of invertebrates includes: protozoans, sponges, roundworms and flatworms, spiny-skinned animals, segmented worms, mollusks, and arthropods.
7. The protozoans, or one-celled animals, are very numerous.
8. Although their bodies are made up of two kinds of cells, sponges are very simple animals.
9. Some flatworms and roundworms are harmful parasites.
10. The earthworm, one of the segmented worms, is an extremely useful soil improver.
11. Starfish are not fish but spiny-skinned animals.

12. Many mollusks, such as clams and oysters, are valuable food animals.

13. The four groups of arthropods, or animals with jointed legs, are: crustaceans, centipedes and millipedes, arachnids, and insects.

14. Vertebrates are animals with backbones. They are more highly developed than invertebrates.

15. The five groups of vertebrates are: fish, amphibians, reptiles, birds, and mammals.

16. Fish are adapted for life in the water.

17. Most amphibians start life in the water, but later they spend all or part of their lives on land.

18. The bodies of reptiles are covered with thick scales and plates.

19. Birds are the only animals with feathers. All hatch from hard-shelled eggs.

20. Mammals are the highest form of animal life. They have hair, or fur, and diaphragms, or breathing muscles. The young are fed with milk produced by mammary glands in the mothers' bodies.

21. Birds and mammals are warm-blooded. All other animals are cold-blooded.

(a) The foregoing sentences are all true statements of important science ideas and understandings. Read and discuss them carefully as a review of this chapter.

(b) The following sentences describe situations in which some of these ideas apply. To test your ability to apply ideas to actual situations, match the sentences in A with situations in B to which they apply.

B

1. Fred Blake compared the empty shells of a clam and a turtle. He found a skeleton inside the turtle shell, but there were no bones in the clam shell.

2. On television, Marilyn Patton saw a film about rabbits. "It's a good thing rabbits can run so fast and hide so well," she said, "otherwise they would never escape from foxes, wolves, dogs, and their other enemies."

3. A muscle of a horse is a highly specialized group of cells. Nevertheless, a muscle cannot remain alive by itself. The lungs of the horse must supply it with oxygen, and the stomach must provide food.

4. Stella Veres and Jane Brown were examining a beautiful feather that they had found. They noticed that when they separated the fine thread-like branches of the vane, they could lock them together again by running the vane through their fingers.

5. Walter Emery read that life on earth began in the sea, and that probably some animals born in the water gradually developed adaptations that enabled them to live on land for longer and longer periods.

6. A large fish can swim swiftly, feeding upon small water animals, including small fish. While very much at home in the water, fish are not considered as high a form of life as other vertebrates.

IMPORTANT SCIENCE TERMS

A

animal kingdom	spiny-skinned animal	vertebra
environment	mollusk	fish
adaptation	arthropod	amphibian
vertebrate	crustacean	reptile
invertebrate	arachnid	bird
protozoan	centipede	migration
sponge	millipede	flyway
flatworm	insect	warm-blooded
roundworm	metamorphosis	mammal
parasitic	spiracles	diaphragm
segmented worm	molt	ruminant

To show that you understand and can use the science terms listed in A, match with the sentences in B those terms that apply.

B

1. Soon after it hatched, a tiny caterpillar began to eat and grow. It shed its skin several times. Later it formed a cocoon from which it finally emerged as a moth.

2. "A salamander looks like a baby alligator," said Gary Fletcher.

"That's not right," Frank Selby argued. "A salamander has a smooth skin, but alligators are covered with large, thick scales."

3. A starfish fastened its foot suckers on the two parts of a clam shell. It pulled and pulled until the clam shell was opened.

4. Birds are thought to possess a "sense of direction" which guides them on their way during their journeys north and south.

5. Earl Crosby carried home a small quantity of water from a stagnant pond. When he looked at a drop of it under a microscope, he saw numerous one-celled animals moving rapidly about.

6. Winter birds and other animals that are active all winter have a body temperature that remains the same in cold weather as it is in summer. They are thus able to keep warm and active even when the temperature around them is very low.

7. One group of vertebrates has a breathing muscle that divides the inside of the body into two parts. This is a characteristic of no other group of animals.

8. Michael Voss was helping his father spray some plants that had become infested with aphids. Mr. Voss explained that the spray would kill the insects by clogging up their breathing pores.

SCIENTIFIC METHOD AND ATTITUDE

1. Mr. Kennedy's class decided to prepare a booklet dealing with the animal kingdom. The problem was what to put in the booklet and how to organize it.

Tony Romano suggested that they go through magazines at home and cut out all the animal pictures. Then they could select for their booklet those that they liked best and could look for information about the animals in them.

Ruth Kelly said that such pictures would be most likely to show common animals and that many animals that should be in the booklet would be overlooked.

Walter Emery thought that they should first consult several authoritative books and make a list of kinds of animals. He felt that they should be careful to arrange the list in the right order and to keep a record of the information that they found. It would then be time to look for pictures.

Which of the above procedures do you recommend? Which follows most closely the scientific method? Why?

2. On the farm owned by Mark Waltman, gophers, commonly called "flickertails," annually caused considerable damage. One day, Mark read that these are not true gophers, but ground squirrels. Their correct name, the book said, is *Richardson's ground squirrel.*

In which of the following ways of thinking would Mark be displaying a scientific attitude?

(*a*) If he thought that the book was written by an authority and that therefore the information must be right.

(*b*) If he thought that it does not make any difference what the animals are called and that he would therefore continue to refer to them as gophers.

(*c*) If he thought that, since his father and every one else in the locality called the animals gophers, the book must be wrong.

(*d*) If he thought that the book might be right but that he would check in another authoritative book. If the two books agreed, he would accept the statement as correct.

A. Devaney Incorporated, New York

I give my pledge as a Canadian to save and faithfully to defend from waste the natural resources of my country — its soils and minerals, its forests, waters, and wildlife.

— Canadian Conservation Pledge

CHAPTER 2

CHAPTER 2

CONSERVING CANADA'S WILDLIFE

Since the days of the pioneers, much of our interesting and valuable wildlife has been depleted, and some animals have become extinct. Even today, many interesting and useful animals are in danger of extinction. Many wild flowers, too, are becoming scarce. What has caused this destruction of wildlife? How can wild animals and wild flowers be conserved? Game laws, fishing regulations, and national and provincial parks aid in the important work of conserving wildlife. How can you help? Do you know how to build a bird house and a winter bird-feeding station? What can you do to help to conserve Canada's wildlife?

GARY FLETCHER, EARL CROSBY, and Bill Curtis planned to go fishing one day in June. After breakfast, they hurried to the trout stream where they hoped to catch the limit permitted by the fishing regulations. An hour passed, then another, but none of the boys felt even a nibble at the baited hooks.

"The fish don't bite here any more," Earl said finally, with disappointment. "And this is the exact spot where Dad says he used to catch fine trout every year."

"I don't think there are as many fish as there used to be," Gary added. "Nobody seems to catch many fish in this stream now. Let's give up fishing for this time."

As the boys trudged home, they discussed reasons for there being so few fish in the stream. "My father says we shouldn't expect as many fish to live here as when he was a boy," Earl explained. "Most of the trees along this stream have been cut down, and the water dries up nearly every summer. Whenever it rains,

soil washes off the hilly fields and makes the water muddy. Fish don't like muddy water; it clogs up their gills and covers up their food and their eggs."

"There are more people fishing in this stream than there used to be," added Bill. "It stands to reason that each person should expect to catch fewer fish now."

"Some people probably have taken more than their share of fish," said Gary. "And others may have caught fish out of season."

"I agree that people probably are partly to blame for the scarcity of fish, but I think there are other reasons," Earl contended. "Last week I saw a hawk eating a fish. Maybe we should get rid of hawks."

Bill disagreed. "I saw a film on television which showed that most hawks are very useful birds."

"Fish aren't the only things that are getting scarce," Earl added. "My brother says there are so few rabbits, pheasants, and wild ducks that it's hardly worth going hunting. He thinks the foxes and owls are to blame."

Again Bill disagreed. "Years ago, when there were plenty of game animals, there were also foxes and owls."

"Yes, you're right," Earl admitted. "It seems that people have caused most of the scarcity of wild animals. I'd like to find out how the shortage has come about, and how we can protect wildlife."

WHY SHOULD WE CONSERVE WILDLIFE?

The term wildlife refers to all wild animals and plants living in their natural surroundings. Wildlife includes mammals, birds, fish, and other animals, as well as flowers and other plants not domesticated by man.

A moment's thought will bring to mind a number of reasons for conserving wildlife.

In Canada, one of the prime uses of wild animals for many years has been for the production of *fur.* Much of Canada was explored and pioneered by fur-trappers. Millions of dollars' worth of Canadian furs are sold at home and abroad each year.

Early settlers depended on wild animals for much of their *food.* Fish, deer, wild ducks, wild pigeons, quail, prairie chickens, bison, and many other animals supplied meat for our forefathers. The pioneers hunted game of necessity; hunters today often seek the same animals for the sport that they afford rather than for the food that they provide.

Much wildlife still provides Canadians with food. Cod, mackerel, halibut, salmon, and a variety of shellfish from our coastal waters provide employment for thousands of Canadians, and supply delicious food for

These pupils are visiting a museum to study the importance of wildlife. They are now getting facts about the value of eagles, owls, and hawks. The girl has brought along a bird book, *A Field Guide to the Birds*, as an additional source of information. (Pendelbury Studios photo)

our table. Our inland waters contribute lake trout, whitefish, bass, perch, pickerel, and other fresh-water fish.

The importance of wildlife to Canadian *agriculture* is too great to be measured accurately. Birds devour numerous weed seeds and insect pests. It has been estimated that a toad is worth $10.00 a year to the gardener because of the vast number of insects it consumes, and that a hawk saves the farmer at least $30.00 annually by devouring gophers, rats, and mice. Frogs and snakes also guard the field against insects. The skunk lives chiefly on beetles, grubs, and grasshoppers. In most cases, foxes deserve protection for their work in catching such rodents as mice and gophers.

Wildlife is also valuable for the *recreation* it affords in a variety of ways. The hunter thinks of a deer as a target to be shot and as venison to be shared with his friends. The

Use these circles, or pie graphs, of the food of three common birds to explain how birds are useful to farmers and gardeners.

angler thinks of a trout as a wary challenge to his skill at casting a fly; the great northern pike is a prize to be displayed proudly to his friends. The camera hobbyist also regards the deer, fox, or Canada goose as a target, to be "shot" with his lens. Even greater skill is required to "shoot" animals with a camera than with a gun, because the photographer must approach them very closely.

Perhaps the greatest enjoyment derived from wildlife is the thrill and satisfaction of seeing, hearing, studying, and sketching our wild neighbors. The bird-watcher rises at dawn to hear the song-birds and to see them near their homes. A person attuned to nature will enjoy the early morning melody of the hermit thrush, the sharp call of the red fox, the honking of Canada geese overhead, the bubbling song of the house wren, the "O-ka-lee" of the red-winged blackbird, the cheery notes of the robin, the drumming of the ruffed grouse, and, after dark, the oft-repeated call of the whip-poor-will, the eerie laugh of the loon, the tremulous whistle of the screech owl, and the chorus of the frogs and toads. Wild flowers, too, provide enjoyment for those who appreciate outdoor beauty.

Canada's wild animals and plants attract many tourists, who come to fish in Canadian lakes, to enjoy the beauty of our scenic areas, and to marvel at the innocence, friendliness, and curiosity exhibited by our wild mammals and birds. The sums of money spent in Canada by our guests

These raccoons come to this feeding station every evening for bread and table scraps. Do you not think that feeding these wild animals would be an interesting hobby? (The Cleveland Press and Glenn Zahn photo)

form an important source of *income* for our country.

When we protect our wildlife, we are improving our communities in many ways — by ensuring a continued supply of animals for food and fur, by protecting crops from plant enemies, by providing recreation for everyone who enjoys outdoor life, and by maintaining, through the tourist industry, an important source of income.

SOMETHING TO DO

1. Make a list of the wild animals that live in your community. Find out how each is useful or harmful. Refer to books, and ask game wardens or conservation officers, and farmers, for information about each animal.

2. Invite a conservation officer or some other authority on wildlife to speak to your class about the value of wildlife and about methods of conserving it.

How man has caused depletion

When white men first came to this country, they found a land in its natural condition. There were clear streams teeming with fish; the rich, green forests abounded with a variety of mammals and birds; the swamps and marshes, thick with water-loving plants, provided shelter for innumerable water fowl. On the prairies, deep with rich grass, great herds of bison and antelopes grazed peacefully. It seemed that every tree, shrub, clump of grass, shaded pool, and patch of open field was some creature's home. In most areas there was a variety of wildlife, some feeding on the rich carpet of grass, others devouring insects, and a few feeding on other small animals.

As you already know, the abundance of wildlife found by the pioneers no longer exists in many parts of Canada. In the lakes and streams near our cities and towns there are few fish to be lured to the angler's hook. In the fields and woods, game animals are scarce. Fewer useful birds inhabit our fields and

"Do you think it is the foxes or the coyotes that are causing the shortage of wildfowl?"

What do you think? *(Nature Magazine)*

Bison grazing in Elk Island National Park, Alberta. What caused the depletion of the great herds of bison that once roamed the prairies? (Canadian Government Travel Bureau photo)

orchards. One can see majestic bison only in parks and game preserves.

Man has brought about the depletion of wildlife chiefly in two ways: (1) *excessive hunting,* and (2) *destroying the habitat in which wildlife lives.*

Excessive hunting

In the days of the pioneers, there were few people in each area, and animals were taken only for food and fur. The few animals that were removed each year had little effect on the total number, because there were plenty of younger animals to replace them.

As more and more hunters entered the field, the natural increase of animals could not keep pace with the number killed, and animals became scarce. Improvements in guns, ammunition, traps, nets, and fishing tackle have given the hunter a great advantage over the animals he hunts, with the result that very few animals survive.

Excessive hunting has caused several creatures to become *extinct,* and others are in danger of extinction. In the days of the pioneers, *passenger pigeons* outnumbered any other kind of bird in North America. When these birds migrated, the skies were darkened for days by their flocks, and wagonloads of them were shot to be sold in the market-places. The flocks diminished rapidly. The last remaining survivor died in 1914. You will never have the opportunity of seeing a living passenger pigeon. Two large mammals, the *eastern elk* and *eastern bison,* were also destroyed by over-hunting. The *kit fox,* once a native of the prairies, has not been reported in Canada for many years.

The *Eskimo curlew* is another bird that has been shot until it is thought to be extinct. The *whooping crane,* the tallest bird in Canada, now numbers less than forty. This huge migratory bird, which nests in a remote spot in the Northwest Territories, is carefully protected in its

A group of passenger pigeons during the spring migration. What brought about the extinction of this bird? (Ontario Department of Lands and Forests photo)

winter home in Texas. Wise conservation practices may save the whooping crane from extinction. The heaviest native bird, the *trumpeter swan,* once nearly extinct, is slowly increasing in numbers under government protection. Among the larger mammals, the *bison,* is an example of an animal hunted almost to the point of extinction, but now thriving in parks and game preserves.

The story of the bison illustrates clearly how quickly a species of animal may be reduced from great numbers down to a mere handful. Before the building of the transcontinental railways and the rapid settling of the prairies, hundreds of thousands of bison roamed the grassy plains in great herds. Whereas the Indians had hunted them largely for food, the new settlers killed them for sport and for their hides. The records of one railway show that in 1870 over 200,000 buffalo robes were shipped to eastern cities; by 1875 so few bison remained that only 300 robes were available.

But the bison was more fortunate than many other mammals and birds. Before it had completely vanished, parks were set aside to protect it. Without government protection, the bison would have been added to the growing list of extinct animals, to be seen only in museums.

The *pinnated grouse,* formerly a common game bird of the prairies, has also been hunted to the point where it may soon become extinct.

The situation is serious. It is not only in Canada that wildlife is being depleted at an alarming rate. In 1958, UNESCO (United Nations Educational, Scientific, and Cultural Organization) made a world-wide study of wildlife problems, and reported some startling facts. It found, for example, that *120 kinds of large mammals have become extinct in the last 150 years,* and that *600 other kinds are on the danger list,* and will almost certainly vanish unless they are protected from the hunter's gun. These figures refer to the number of large mammals only. You can imagine how much greater the number of extinct and nearly extinct animals would be if the list had

included all the smaller mammals, birds, reptiles, and other animals that have been killed off or are rapidly vanishing. The protection of the world's wildlife is a vital problem.

Sometimes the excessive hunting of wild animals has a serious effect on the livelihood of man. Some years ago, the *Pacific fur seal,* which provides pelts for seal coats, became so scarce that laws had to be made to protect it. As a result, the number of seals increased, and a certain percentage of them may now be killed each year.

International agreements have also been made to control the number of *whales* taken from the oceans each year.

For hundreds of years the Eskimos of northern Canada have relied on the *caribou* for food. The introduction of firearms has greatly reduced the number of caribou in many parts of the north. The *muskox,* a large unusual, cow-like mammal of the Arctic, has also disappeared from much of its former range.

We must determine to put an end to all excessive hunting and to stop all sports hunting of animals that are nearly extinct. Animals in danger of extinction should be protected in natural parks where hunting is prohibited. If we fail to do this, many of the animals that are familiar to us today will be the fossils of tomorrow.

How habitats are destroyed

Every animal has a certain kind of area in which it thrives. The type of region in which an animal naturally lives and grows is called its *habitat.* The habitat must supply the animal with the things it needs — food, water, and suitable cover, in which it can hide or escape from its enemies. For example, the habitat of wild ducks is along the shores of ponds and marshes, where the shallow water provides tiny plants and animals for food, and where the reeds, grasses, and shrubs afford a hiding place for the nest. The habitats of various kinds of animals are very different. For example, consider the habitats of the black squirrel, the gopher, and the beaver. The squirrel lives high among the branches of forest trees, the gopher in a hole in open prairie, and the beaver in a lodge in a pond or stream. Each animal chooses the habitat that best supplies its needs.

When an animal's habitat is changed or destroyed, the animal must move out or die because of lack of food, water, or protection. When the pioneers cut the forests, most of the raccoons, squirrels, mink, and foxes, and many song-birds, were greatly reduced in number. When man ploughed the fields and open prairies, he destroyed the habitat of the prairie chicken, the bison, the antelope, and the prairie dog. In many places, marshes and swamps have been drained to provide more land for agriculture; as the water disappeared, beavers, muskrats, wild ducks, and many other water-dwelling creatures also vanished.

Most game fish, such as the trout, require cool, clear streams, where they

can hide among water plants, feed on water insects, and lay their eggs in the clean gravel on the stream bed. When forests are removed, there is no shade to keep the water cool. The removal of forests permits snow to melt rapidly, causing spring floods. In a forest, the spongy forest floor soaks up excess water, letting it run away slowly, thereby maintaining the level of the streams. However, when forests are cut down, streams dry up in summer, and the fish perish. Soil from eroded hillsides on improperly managed farms makes the water muddy and unsuitable for game fish. In some communities, untreated sewage and factory wastes are poured into lakes and streams, making the water poisonous for fish.

Wild flowers, too, have their own habitats. Flowers of the deep, moist woods disappear when forests are removed, and wild flowers of the open fields and prairies die out when their habitats are ploughed under. We must conserve some of our forests, swamps, and open prairies in their natural state to protect our beautiful wild flowers.

SOMETHING TO DO

1. List the animals living in or near your community that require the following habitats: deep forests, open forests, marshes, open fields, ponds, clear streams. Do not list only *mammals;* include several additional groups of animals, such as *birds, amphibians, reptiles,* and others (see pages 54 to 72).
2. List wild flowers of your province that live in the following places: shady forests, marshes, open fields (see pages 110 to 115).
3. Find out what mammals were common in your area before the land was cleared.
4. In reference books, find information and prepare reports on the following extinct animals: great auk, passenger pigeon, heath hen, Labrador duck, giant sea mink, eastern bison, eastern elk. Find out what caused each to become extinct.
5. Find out how to recognize the following creatures that are in grave danger of becoming extinct: whooping crane, trumpeter swan, ivory-billed woodpecker, Eskimo curlew, bison, kit fox, pinnated grouse. What has caused their depletion? What is being done at present to protect them from becoming extinct? Bring to school newspaper and magazine articles on some of these animals.

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. What is meant by the term "wildlife"?
2. Why should wildlife be conserved? Answer this question under the following headings: food, furs, tourist attraction, beauty, sport, destruction of pests.
3. What are the two chief ways in which man has caused the depletion of wildlife?
4. What is meant by an animal's "habitat"? Name one common mammal and one bird, and describe the habitat of each.

Whooping cranes on their nesting grounds in the Northwest Territories. What is being done to conserve this rare bird? (Saskatchewan Government photo)

5. How do the following practices affect wildlife: cutting down forests, draining marshes, pouring untreated sewage into streams?

THE BALANCE OF NATURE

Most small animals reproduce at an amazing rate. For example, a female frog lays thousands of eggs each year, but only a very few of them become adult frogs. A pair of mice would reproduce hundreds of mice in one year if they had no enemies to keep them in check. Insects reproduce at an even greater rate. It has been estimated that in one summer the descendants of one pair of house flies, if none were killed, would be so numerous that they would cover a large city to a depth of 200 feet!

Perhaps you wonder why we are not overrun with the hosts of small animals. One reason is that there would not be enough food for all of them. Another is that larger animals keep them in check by using them for food. Every small animal is in a constant struggle for existence — to find enough food and water, and to escape its enemies. Out of this struggle there results a balance in the number of each kind of living thing. It is called the *balance of nature*.

Let us study an example to see how the balance of nature operates. Suppose that some summer there is a large number of field mice in an area. With plenty of food and favorable weather, the mice will continue to multiply rapidly. Hawks, owls, and foxes, which feed on mice, will now

The snowy owl is a flying mousetrap. In summer it lives in the far north. In winter it may move to southern Canada. (C. G. Hampson photo)

Many of our birds of prey have been widely persecuted as a result of prejudice and lack of information. Actually they are of great help in rodent control, and are thus friends of the farmer. This prairie falcon was observed feeding its brood on 34 occasions. During these trips, 33 rodents were brought to the nest. (C. G. Hampson photo)

Without animals to keep them in check, many mice and other rodents would become too numerous. Weasels are efficient mousers that help to maintain a healthy balance in the wildlife community. The long-tailed weasel, shown in the photograph above, is one of the kinds that turn white in winter. (C. G. Hampson photo)

A sparrow hawk coming in for a landing. This useful hawk feeds chiefly on grasshoppers and mice. (C. G. Hampson photo)

find plenty of food. They will be able to raise large families of well-fed, healthy young. As the number of these predators increases, greater numbers of mice will be eaten. This will continue until the number of mice begins to decrease. As mice become harder to find, some of the predators will die or move to better hunting areas. In a year or two, mice and predators will be back to their usual numbers.

A similar balance exists between insects and song-birds. Under natural conditions, an increase in the number of insects is offset by an increase in the number of birds that feed upon them.

For many years, it has been observed that the varying hares of the prairies and northern forests increase in number for several years and then nearly disappear, only to increase again. Studies have shown that as the number of hares increases, predators such as the lynx, coyote, and timber wolf also multiply, nourished by the numerous hares. Finally, the predators become so numerous that they reduce the number of hares, and the balance is restored. Disease, too, which spreads rapidly when animals become too numerous, tends to reduce the number of animals and to restore the balance of nature.

These examples show how, in an area undisturbed by man, the balance of nature controls the numbers of the various animals living there.

What is a food chain?

It is usually difficult to decide whether an animal is useful or harmful until we understand its feeding habits. As you know, field mice eat large quantities of grain. Most owls live chiefly on mice. These three living things, wheat, field mice, and owls, are linked together by their food habits. Such a series of living things is called a *food chain*. Wheat, field mice, and owls are the links in this food chain. Use your understanding of this food chain to explain why most owls are useful birds.

SOMETHING TO DO

1. Wolves, deer, and young trees are three links in a food chain. What damage may be done to a forest if deer become too plentiful? Explain why wolves may be useful animals when there are too many deer in one area.
2. Skunks, potato beetles, and potatoes are links in a food chain. Why is a skunk a useful animal where potatoes are grown?
3. The greatest enemy of the song-birds of our gardens is a house cat that is allowed to roam about. Insect damage to a garden may result when a cat is allowed to wander. What are the four links in this food chain?
4. You are a link in many food chains. Grass, cows, and man form a food chain. Wheat, hens, and man form another. What are some other food chains in which you are a link?
5. Figure out food chains that include common animals and plants of your community. In each, which living things are useful to us, and which are harmful?

How man upsets the balance of nature

When man changes an area by ploughing fields and cutting forests, he destroys the habitats of some animals, and thus may upset the balance of nature. For example, cutting down trees causes a decrease in the number of song-birds; as a result, harmful insects increase without being consumed by their natural enemies, the birds.

Man also upsets nature's balance by killing off useful animals. As you know, if most of the hawks, owls, and foxes in an area are destroyed, mice and other pests go unchecked. If skunks are exterminated, or useful birds killed, insects and weed seeds may go uncontrolled.

Another way in which man has affected the balance of nature is by bringing new species of animals to our country. Such destructive insects as the Colorado potato beetle, the Japanese beetle, the European corn borer, and the imported cabbage butterfly have been able to increase rapidly because they have had, in this country, few natural enemies to keep them in balance. The folly of importing animals into areas where they lack natural enemies is very evident in Australia, where the greatest farm problem is the need of exterminating the millions of rabbits that eat much of the grass required for grazing sheep. These pests descended from a few pairs released many years ago. Because they had no natural enemies in their new habitat, the rabbits multiplied so rapidly that they have become destructive pests.

In our own country, two imported birds, the *starling* and the *English sparrow*, have become two of our worst pests.

The starling — bird enemy number one

In 1890, a few starlings were brought to North America from their native Europe. For a few years they were seldom noticed. However, because they had no natural enemies on this continent and because they found plenty of nesting sites in holes in houses, barns, and trees, they increased rapidly. At present, starlings are the most common birds in eastern North America. They have also moved into various parts of the prairies, and have been observed on the west coast.

In limited numbers, starlings are not harmful birds. In fact, they eat

A starling emerging from a flicker's nesting hole which it has taken over to raise its own brood. Why have starlings become so numerous in eastern North America? (Hugh Halliday photo)

many destructive insects. However, as their numbers increase, they drive away many other birds. In many areas, starlings have caused the disappearance of the bluebird, the flicker, and the red-headed woodpecker, whose nesting holes they take over to raise their own broods. In the colder months, starlings become nuisances in cities and towns, where they gather in noisy flocks numbering in the millions.

Starlings have increased because nature's balance has been upset. The greatest hope for restoring a proper balance is that certain predators will begin to prey on them. Scientists have found that several kinds of hawks and owls have added the starling to their diet. This is yet another reason why hawks and owls should be conserved.

Other harmful wildlife

In its natural habitat, every living thing plays its part in nature's plan. However, some creatures compete with or destroy useful plants and animals raised by man, and must be controlled. You know that weeds must constantly be kept in check. Likewise, we must control harmful insects such as grasshoppers, potato beetles, tent caterpillars, cabbage butterflies, cutworms, and a host of other six-legged pests.

Among the mammals, only a few, such as house mice, field mice, rats, and gophers are almost always harmful. Others, such as coyotes, wolves, and foxes are sometimes harmful, but often play an important part in maintaining the balance of nature. Thus it is unwise to destroy such animals without first studying their food habits in the area where they live. Informed people maintain that these predators, as well as most kinds of hawks and owls, are usually useful.

SOMETHING TO DO

1. Discuss the question of predators with hunters, farmers, and naturalists. Try to decide whether opinions about hawks, owls, and foxes are based on fact or prejudice.
2. If a hawk is seen eating a chicken, should we conclude that all hawks are harmful, and set out to destroy them? Why? What would be a better policy?
3. Find in a bird book some facts about the number of mice eaten by various kinds of owls.
4. A naturalist examined a rabbit that had been killed by a hawk, and found that the rabbit was diseased. Discuss the importance of the hawk in this instance.
5. Crows are often regarded as pests. Discuss this opinion with farmers, and check bird books for facts about crows.

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. What is meant by "the balance of nature"? Use an example to show how this balance operates.
2. Describe two ways in which man has upset the balance of nature.

3. Name the living things that make up any one food chain. Why do we call it a food chain?

4. Skunks are fond of turtles' eggs. When turtles become too numerous, they often catch baby ducks. Explain how ducks in a lake are protected by skunks. What are the links in this food chain?

5. Name two harmful animals, and tell why they must be controlled.

6. Why has the starling become the most common bird in eastern North America? What harm is done by this bird?

7. What is meant by the term *predator*? Name three useful predators. How is each beneficial?

HOW CAN WE CONSERVE WILDLIFE?

When our forests and grasslands were cleared and ploughed for agricultural use, little thought was given to protecting wildlife. Today, however, it is recognized that wildlife is useful and can be raised along with farm crops and forest trees. Good farming and lumbering practices protect the habitats of many wild animals. For example, the farmer who plants windbreaks and lets trees and shrubs grow along his fence rows protects his crops from the wind and also provides homes for birds and game. These animals pay their rent by eating insects and weed seeds. Wise farming practices that prevent soil erosion help to keep streams clear so that fish may thrive. By removing only mature trees, the lumberman preserves the habitats of deer, foxes, and birds. By preventing and controlling forest fires, we protect wildlife as well as trees. Thus it is possible to use farmlands and forests without destroying wildlife. In cities, too, many useful kinds of wildlife will live if we conserve suitable habitats for them in the form of natural parks.

The responsibility for conserving wildlife must be shared by our governments, by farmers and lumbermen, and, most important of all, by every individual.

The work of governments in wildlife conservation

Our governments help to conserve wildlife chiefly in three ways: by establishing and enforcing game laws and fishing regulations, by restocking suitable habitats with game and fish, and by setting aside areas with suitable habitats for kinds of wildlife that might otherwise be exterminated.

Game laws

Because the wildlife of a country belongs to all the people, it is the responsibility of the government to

make sure that it is used to benefit everyone.

SOMETHING TO DO

Obtain copies of the game laws and fishing regulations for your province. Find out whether there are regulations controlling the following in your locality: open and closed seasons, bag limit, types of weapons, lures and nets, licences, legal size.

Make a list of six animals (mammals, birds, or fish) protected in your area, and list the regulations protecting each.

Various regulations are used to conserve each kind of animal. The game laws are based on a knowledge of the animal and its habits. Sometimes a *census*, or count, of the number of animals in an area is taken to provide information on which to base the laws. As the numbers of animals and hunters change, the laws are revised to suit the new conditions. Conservation officers or game wardens are employed to see that the regulations are followed.

Closed seasons, when hunting and fishing are prohibited, are essential in conserving wildlife. Most game mammals, birds, and fish are protected during the seasons when they are raising their young. In many areas, a short *open season* is permitted for hunting deer, moose, and pheasants. Longer open seasons are usually permitted for taking rabbits, wild ducks and geese, and most kinds of fish.

White pelicans in flight over Old Wives' Lake, Saskatchewan. Such interesting water birds can be conserved by leaving their nesting grounds in their natural condition. (Hugh Halliday photo)

The government also restricts the *bag limit,* or number of each animal that each hunter may take. Why is this a good idea? In answering this question, remember that wildlife belongs to everyone.

In some areas, hunters may shoot only the male animals of such species as deer, moose, and pheasants, leaving the females to reproduce.

Most game animals may be hunted only with certain types of equipment. For example, game mammals may not be taken with nets, traps, or snares, and most fish may be taken only with hooks and lures. Why are these regulations necessary?

Years ago, when wild animals were plentiful, it was legal to sell game. Why is "market hunting" now forbidden in most places?

Why do governments require hunters to buy a licence if they wish to hunt? Why are non-residents required to pay higher licence fees than residents of the locality must pay?

Many kinds of fish, such as trout, bass, pickerel, and sturgeon are conserved by permitting the fishermen to keep them only if they have reached a certain length. Why is "throwing back the small ones" a good conservation practice?

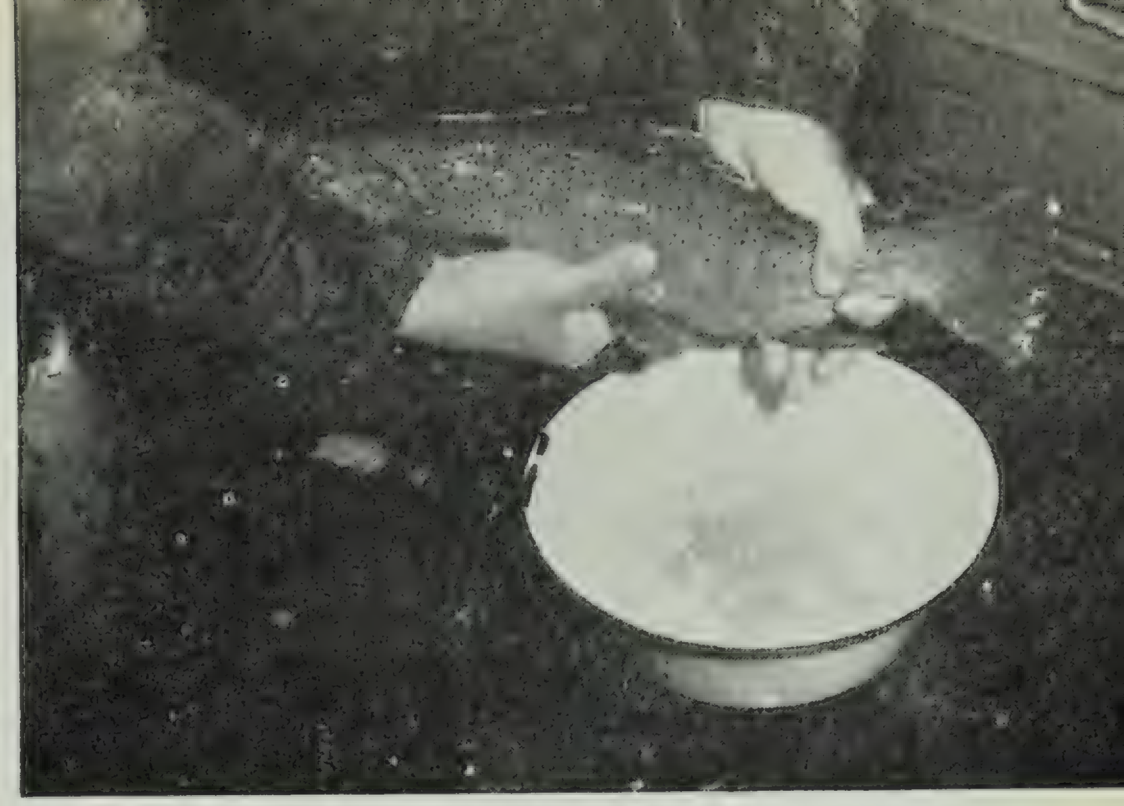
Many other types of laws are used to conserve game in various parts of Canada. For example, most animals may be hunted only in the daytime. Wildfowl are often given some protection by permitting the hunter to have only a certain number of shells in his gun.

To restock an area with pheasants, adult birds are kept in pens and cared for like chickens. Their eggs are hatched in incubators. These pheasant chicks are only an hour old. In a few weeks they will be large enough to be released in a suitable habitat. (Ontario Department of Lands and Forests photo)

Restocking the woods, fields, and streams

In some provinces, the government raises wild animals for the purpose of releasing them to provide game for the sportsmen. Pheasants and bob-white are hatched in incubators and released in large numbers. By caring for these young birds for some weeks after they hatch, until they are large enough to take care of themselves, it is possible to protect them from unfavorable weather conditions and from the dangers that they would meet in their natural habitat.

Most kinds of fish lay thousands, or even millions of eggs, but few of them hatch and mature because many creatures feed on fish eggs and baby fish. At fish hatcheries, the eggs of game fish, such as trout and bass, are collected and hatched under ideal conditions. The young fish are properly fed and protected until they are several inches long. They are then released in streams that have suitable



The eggs, or spawn, are squeezed from a brown trout at a fish hatchery. Later, the eggs will be hatched under ideal conditions. When the baby fish are large enough, they will be released in clear streams. Why does this method of reproduction result in a greater supply of fish than when the fish lay the eggs in the stream? (Ontario Department of Lands and Forests photo)

habitats for them, but in which there is a scarcity of game fish.

Sometimes larger animals also become scarce or extinct in areas where there is a suitable habitat for them. When this happens, animals from overcrowded districts are moved to the depleted area. Deer, moose, and beaver have been transferred successfully to more suitable locations.

Game preserves and wildlife sanctuaries

To supply better protection for wildlife, and to provide citizens and tourists with opportunities to observe, study, and enjoy nature's wild creatures, governments and individuals have set aside areas where no hunting is permitted. Our federal government has reserved many large areas as *national parks,* and the provinces have provided many *provincial parks.* In most of these areas, we find scenes of rare natural beauty — thick, towering forests, rugged mountain slopes, and cool, clear lakes and streams. Here the visitor may see bighorn sheep, Rocky Mountain goats, bison, moose, and other animals which would be exterminated without such protection. Fishing is permitted, but the visitor is not allowed to shoot or trap other wild animals. The naturalist, hunting with a camera instead of a gun, finds a host of subjects. Birds and their nests are seen close at hand; even the deer and bears are unafraid of the visitors.

SOMETHING TO DO

1. On a map of Canada, locate some of the following national parks in which interesting wildlife may be seen: Glacier, Yoho, Kootenay (British Columbia); Jasper, Banff, Waterton Lakes, Elk Island, Wood Buffalo (Alberta); Prince Albert (Saskatchewan); Riding Mountain (Manitoba); Point Pelee (Ontario); Fundy (New Brunswick); Cape Breton Highlands (Nova Scotia).
2. On a map of your province, locate the provincial parks. Find out what animals are protected in these parks.

Our governments have also set aside *game preserves* in which hunting is prohibited. Naturalists often establish *bird sanctuaries* where birds

Animals like these are being saved from extinction in our national and provincial parks. The animals shown here are, bottom left to top right, a pair of Rocky Mountain goats, twin moose calves, and a friendly deer. (Canadian Government Travel Bureau photos)

may find a safe habitat during migration and the nesting season.

In various parts of the prairies, a movement known as "Ducks Unlimited," organized by sportsmen, has done much to improve the habitats of wild ducks. The work of this organization in restoring ponds and marshes has provided more breeding grounds for waterfowl, and has resulted in an increase in the number of these birds.

The governments of Canada and the United States have acted together to protect migratory birds, by passing laws prohibiting the shooting of game birds except in open season, and protecting migratory song-birds at all times. The fact that international co-operation exists to protect birds emphasizes the importance of wildlife conservation.

How farmers and lumbermen can aid in wildlife conservation

The farmer who follows wise soil-conservation practices is aiding wildlife as well as protecting his crops. Windbreaks reduce wind erosion and act as homes for wildlife. The prevention of soil erosion keeps streams clear for fish. The farm woodlot provides homes for animals, and aids in conserving soil water, in addition to supplying fuel and logs. Marshes, the natural homes of wildfowl and muskrats, should be left in their natural condition wherever possible. In many areas, marshes that were formerly drained are being restored to provide

habitats for wildlife, and to conserve water for nearby farms.

Good forest conservation goes hand in hand with the conservation of wildlife. Forest fires must be prevented to conserve trees, wild flowers, and animals. By practising selective cutting, the lumberman assures himself a continued tree harvest, and provides birds and mammals with food and shelter. On the other hand, excessive cutting of forests causes a long delay before trees will be available again, and at the same time drives out much useful animal life. Birds and mammals reward good forestry practices by ridding trees of insect pests. A few dead trees left standing will attract the woodpeckers that eat bark insects, and will serve as homes for the squirrels that plant large numbers of acorns and other tree seeds.

Canada geese and other birds find food and protection at the Jack Miner bird sanctuary near Kingsville, Ontario. Here, whistling swans are being fed. Among the other birds can be seen pigeons, male and female mallards, Canada geese, blue geese, and a snow goose. (Ontario Department of Lands and Forests photo)

Conservation is an individual responsibility

The work of governments, farmers, and lumbermen in conserving wildlife must be aided by law-abiding sportsmen, fishermen, and other citizens. Informed conservationists regard wildlife as a product of the land, with a surplus that may be harvested once a year, during the open season. Game laws are designed to make sure that only the surplus is removed, so that enough wildlife will be left to reproduce.

Wildlife belongs to everyone. All of us have a right to use it by hunting it in season, observing it, and benefiting from the many ways in which it serves us. The individual who takes more than the legal limit of game or fish, or hunts out of season, or keeps undersized fish, or in any other way takes more than his share of wildlife is a poor sport and a poor citizen.

You live in a land that in many areas is still rich in wildlife, soil, forests, water, minerals, and other natural resources. You have a right to use these resources, but you also have a responsibility to use them wisely, so that generations of people not yet born may enjoy them as you have.

The white trillium (left) and the red or wild orange lily, also called the prairie lily, are the floral emblems of Ontario and Saskatchewan, respectively. Why should we not pick these flowers? (Hugh Halliday photos)

Let us remember to use wildlife and other resources in ways that do not waste and destroy them.

Wild flowers — to be enjoyed but not destroyed

Today there are fewer of our beautiful wild flowers than there were a century ago. Unless we conserve the ones that we still have, future generations may be deprived of the enjoyment of seeing them.

Wild flowers have been destroyed in two ways – by destruction of their habitats, and by unwise picking. As you know, when forests are completely cleared by cutting or fire, when swamps and marshes are drained, and when open fields are ploughed, the wild flowers living in these habitats disappear. By saving some of these habitats through wise lumbering practices, preventing forest fires, retaining marshes, and leaving some open areas permanently in grass, we may help to protect wild flowers.

Every individual can help to conserve wild flowers by refraining from picking them. Enjoy the beauty of these plants in their natural setting, but let them continue to grow, so that the flowers may produce seeds, and the leaves of those that are perennials may produce enough food for the root or bulb to store away the supply it needs to bloom the next year.

SOMETHING TO DO

1. Make a number of field trips during the spring and summer, to learn to recognize the wild flowers of your area. Learn by observation that each type of habitat has its own group of wild flowers. For example, in warm, open woods you may find bergamot, fairybells, bunchberry, twinflower, anemone (or wind-

flower), and prairie lily; in damp woods, the lady's-slipper; near marshes and ponds, the wild iris, arrowhead, cat-tails, and marsh marigold; in open fields, the pasque flower (prairie crocus), bluebell, gaillardia, wild aster, goldenrod, and black-eyed Susan. On your trips, watch for other wild flowers found in each habitat.

2. Examine the plant and flower of the prairie rose, or wild rose, the floral emblem of Alberta. In what type of location does it grow? What natural protection does this plant have?

Fairy Bells. (W. C. McCalla photo)

Above, prairie rose, or wild rose, floral emblem of Alberta. Below, dotted blazing star. (Hugh Halliday and W. C. McCalla photos)

Three wild flowers of Alberta are the flowering raspberry (left), the anemone, or windflower (centre), and the golden pea (right). (United States National Park Service and W. C. McCalla photos)

Sun flowers grow in a sand dune (left). Bergamot (above). (Photos by Wisconsin Conservation Department and Dr. L. G. Saunders)

Twin flowers (left) and early yellow loco-weed (right). (Dr. L. G. Saunders, W. C. McCalla photos)

3. If possible, take with you on your trips a handbook of wild flowers to help you in identifying them, or bring back *one only* of each kind of wild flower so that you may find it in other books of wild flowers. Picking only one for identification from a large group of flowers will do little harm. However, do not pick a bouquet.

Nuttall's yellow violet. (W. C. McCalla photo)

Six wild flowers that are common in some parts of the Prairie Provinces and in some other parts of Canada are (reading from top left to right and bottom left to right): Canada violet; pasque flower (wild crocus), the provincial floral emblem of Manitoba; tufted fleabane daisy; black-eyed Susan; gaillardia; long-headed coneflower. Watch for these and other wild flowers. (Hugh Halliday and W. C. McCalla photos)

4. A careful study of either the prairie lily or the white trillium (the provincial flowers of Saskatchewan and Ontario, respectively) will help you understand why we should not pick these flowers. In picking them, you remove most of their leaves, or in the case of the white trillium, all of them. Carefully dig up the roots of *one* of these plants as a specimen for your class. Did you find a bulb? When the leaves are picked, the bulb dies. Why?

5. Many of our wild flowers will thrive in your home garden, if you provide conditions similar to their natural habitats. Some will grow in a sunny spot in your garden, others in the shade, and some around a lily pond. In transplanting them, carefully dig up the entire root system. If possible, leave a ball of soil on the roots. Plant them in the same conditions of shade, sun, and moisture as in the place where you found them.

6. Prepare a chart showing wild flowers of your area that need protection.

7. Take a camera with you on your field trips. Wild flowers are beautiful subjects for the camera hobbyist. With black-and-white or color film, you will be able to bring back a permanent record of the beauty that you have seen. This is another interesting way of enjoying wildlife without destroying it.

These six wild flowers (reading from top left to right, and bottom left to right) may be seen in the woodlands of southern Ontario and some other parts of Canada: hepatica, pale mauve in color; dog's-tooth violet or adder's tongue; bloodroot; yellow lady's-slipper; Jack-in-the-pulpit; Dutchman's breeches. Enjoy the beauty of these flowers in their natural habitats, but do not pick them. (Hugh Halliday photos)

Bunchberry, or ground dogwood. (National Park Service, Washington, photo)

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. Briefly describe four kinds of game and fishing regulations. Tell why each law is useful in conserving wildlife.
2. Why does the government restock some areas with certain kinds of wildlife? What animals are often raised for replenishing the supply?
3. Why have our governments set aside our national and provincial parks?
4. Briefly tell two ways in which good farming practices improve the habitats of wildlife.
5. "The person who takes more than his share of game and fish is a poor sport and a poor citizen." Explain.
6. "Good hunting practices are designed to harvest only the *surplus* wildlife." What do you understand by this statement?
7. Name four wild flowers of your area. In what kind of habitat is each one found?
8. In what ways can wild flowers be protected?
9. Describe two ways of enjoying wild flowers without destroying them.

HELPING TO CONSERVE OUR BIRD FRIENDS

Many people who observe and enjoy the wonders of nature consider birds the most interesting of all animal groups. The great number and variety of birds, their bright colors and cheerful songs, their remarkable nesting habits, their unusual adaptations, and the fact that many of them live close to our homes, makes them a favorite and ideal group for observation.

Birds are worthy of special attention in our study of the conservation of wildlife. Do you realize that birds perform many valuable services and play a vital part in the balance of nature? Do you know any ways in which *you* can help to protect and conserve birds?

The black-capped chickadee is one of our most beloved birds. Sometimes these brave little birds will come to your hand for food. Chickadees eat countless numbers of insect eggs in winter. (C. G. Hampson photo)

Why should we protect birds?

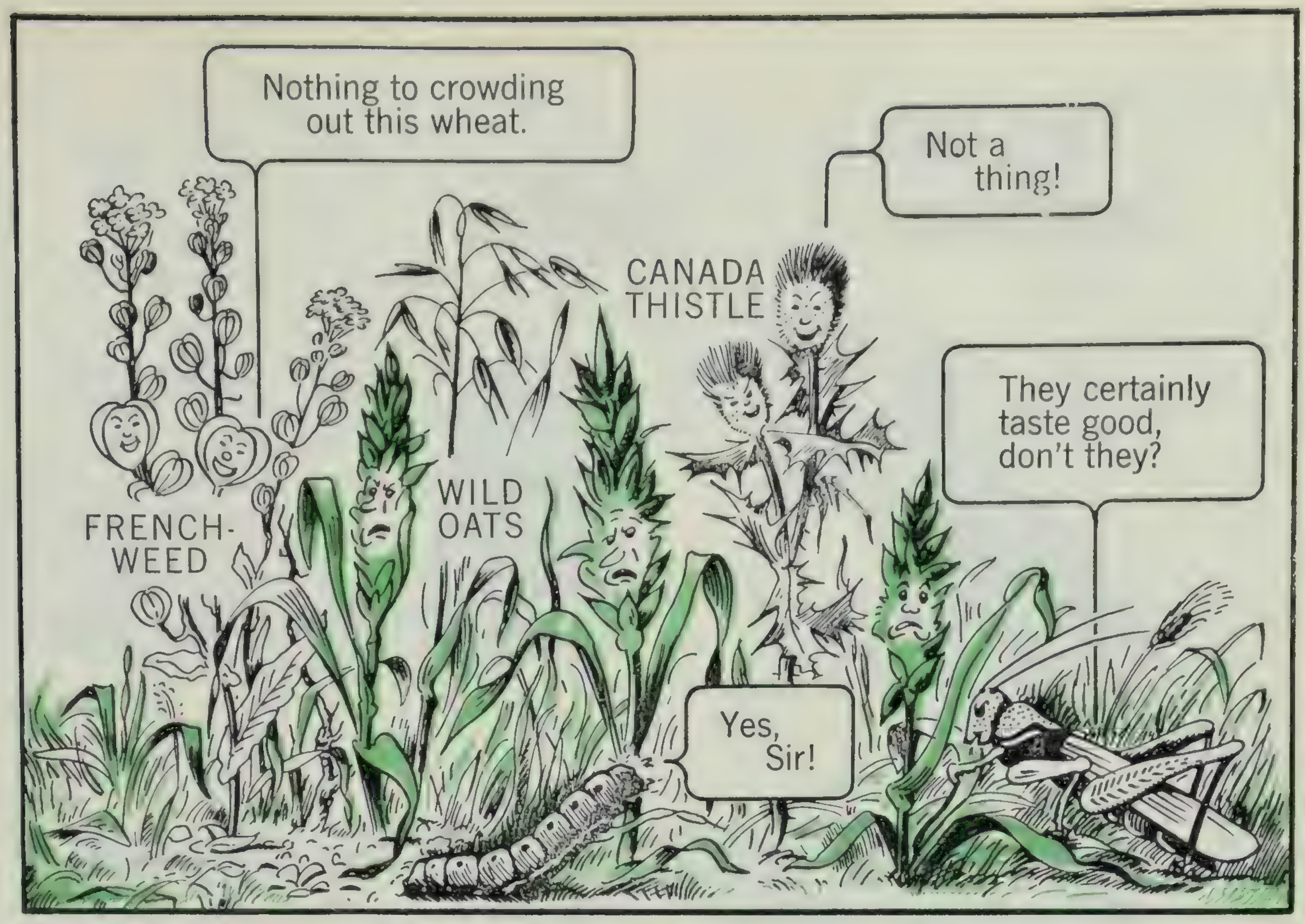
In addition to entertaining us with their bright colors and sweet songs, our feathered friends perform another useful service by eating numerous weed seeds, harmful insects, and destructive rodents. It is impossible to measure in dollars the value of the work done by birds.

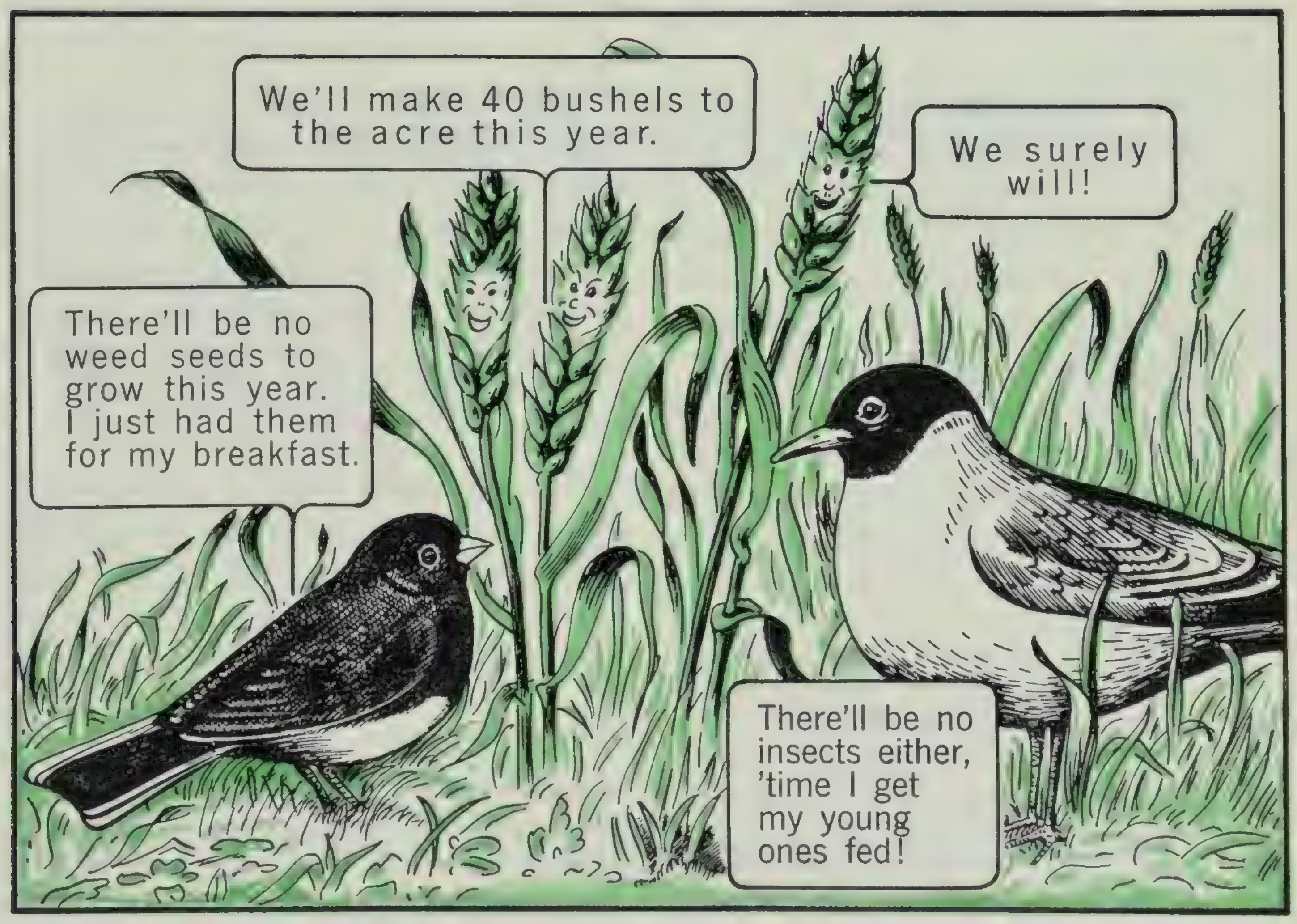
The box below contains factual information about the diet of six well-known birds. These amazing facts illustrate the importance of such birds to the farmer and gardener.

1. A family of house wrens eats 1000 harmful insects daily.
2. A flicker eats 1200 ants a day.
3. A rough-legged hawk eats 1 gopher or rat, or 5 field mice daily.
4. In one month, a snowy owl eats 400 mice.
5. A slate-colored junco consumes 3000 weed seeds a day.
6. During one evening, a night-hawk catches 1000 flies, moths, and mosquitoes.

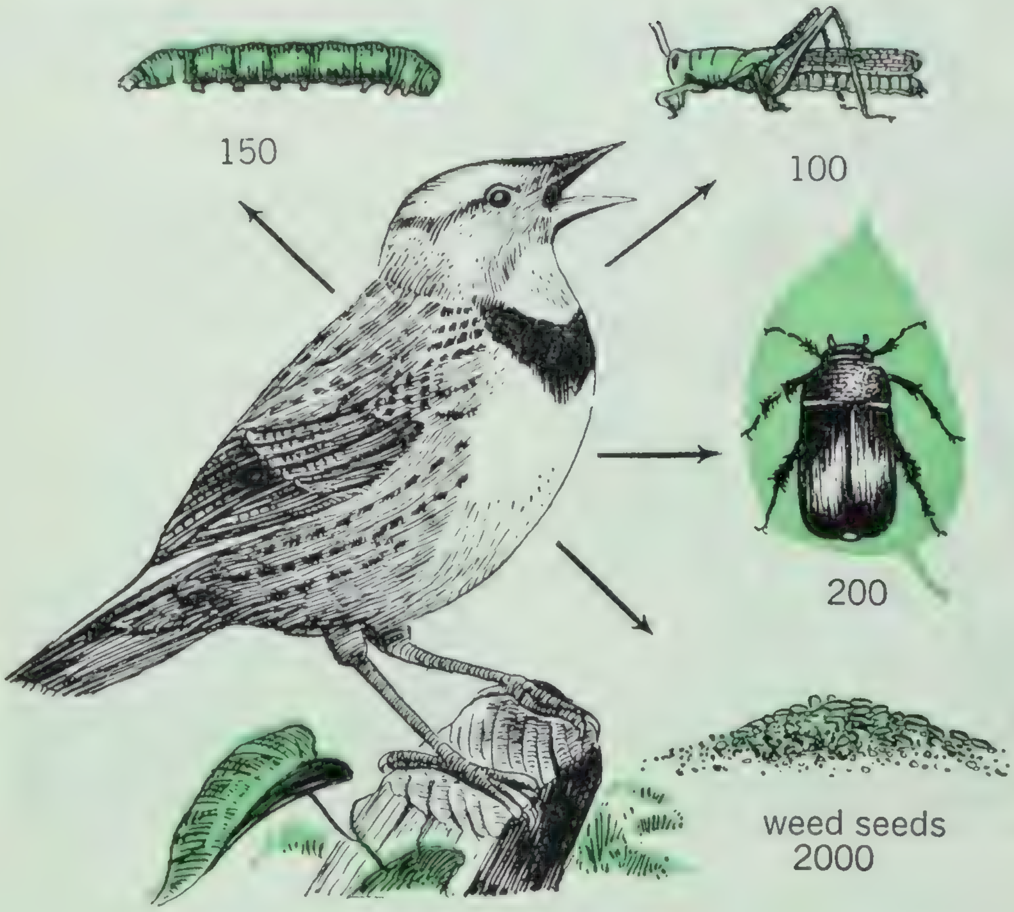
Flying mousetraps

Hawks and owls have been among the birds most persecuted by man, but authorities consider them to be among the most useful birds. By day





Tell the story of this illustration in your own words. Why should our bird friends be protected? The two birds shown here are the slate-colored junco and the Franklin's gull.



The daily menu of a meadowlark. Because they eat so many weed seeds and harmful insects, meadowlarks are among the farmer's best friends.

and night they guard the fields against destructive pests. By studying the diagram on page 119, you will find that an analysis of the stomach content of various hawks common in many parts of Canada shows most of these kinds of hawks to be very useful to the farmer. Similarly, owls live chiefly on mice. At one barn owl's nest were found 3000 skulls of mice and rats, grim evidence of the diet of a brood of young owls.

Occasionally a hungry hawk steals a chicken. When this happens should we conclude that *all* hawks are harmful, and decide to destroy them? Would it not be wiser to shoot only the offender? Informed conservationists do not kill hawks and owls. Hunters who understand the value of these flying mousetraps do not shoot them.

SOMETHING TO DO

Be sure that you are open-minded about the importance of hawks and owls. Look up more facts about them and report the information to your class. Check your findings with the chart on page 119.

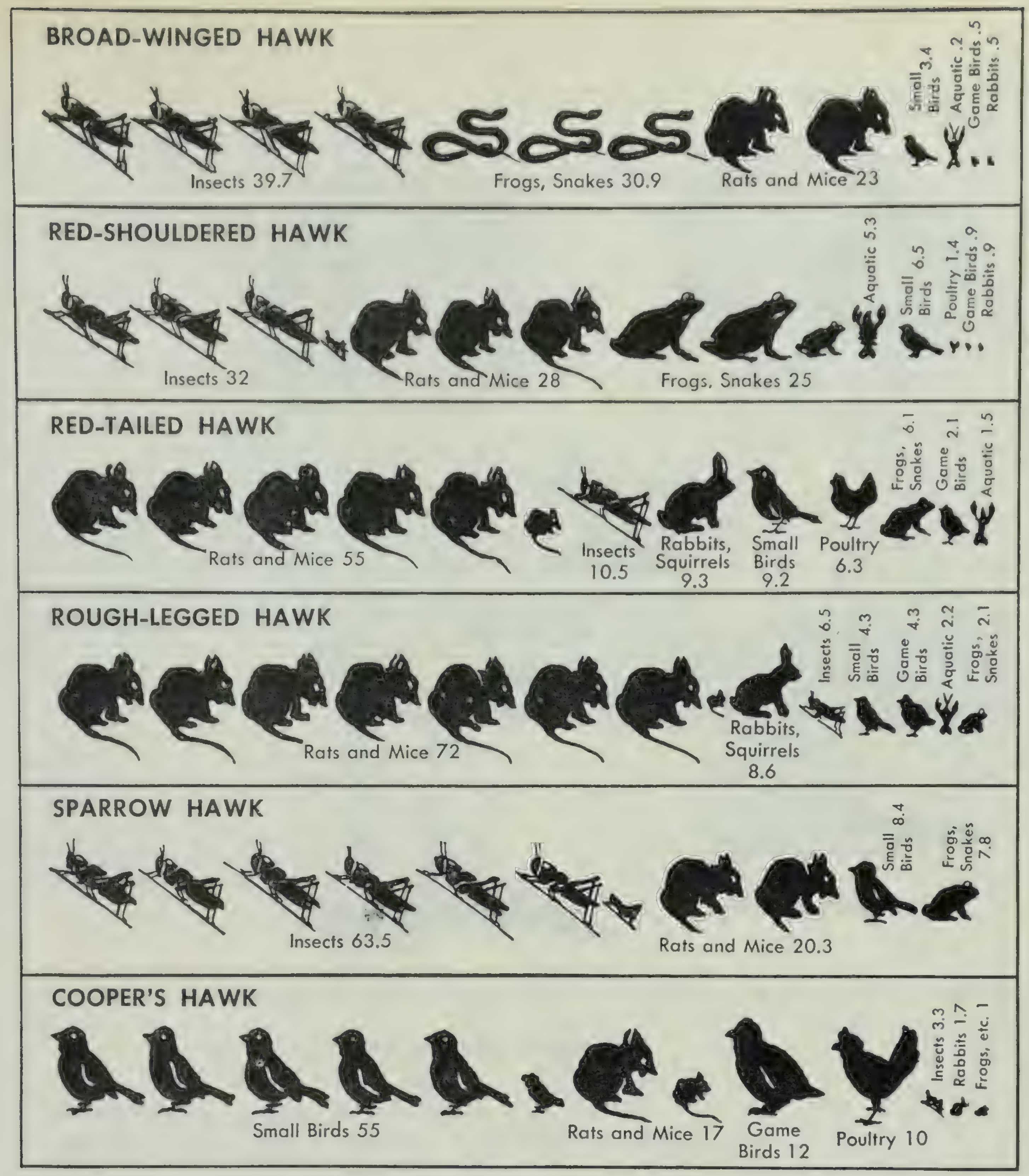
How we can help to conserve birds

You already know a number of ways in which governments protect game birds and song-birds. There are several ways in which you as an individual can aid and protect birds.

SOMETHING TO DO

1. If you own a cat, prevent it from roaming into gardens and shrubbery. Cats are the worst single enemy of the song-birds in your garden.

2. Be sure that you and your friends do not molest birds' nests. Above all, do

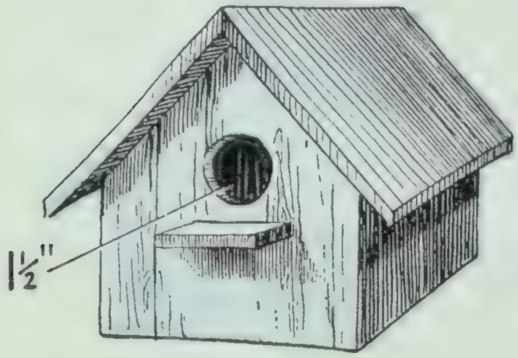


This picture graph shows the diets of six common hawks. Which ones are the most beneficial? Which is the only one of the group that should be classed as harmful? What conclusion about hawks can you reach from studying this graph? (National Audubon Society)

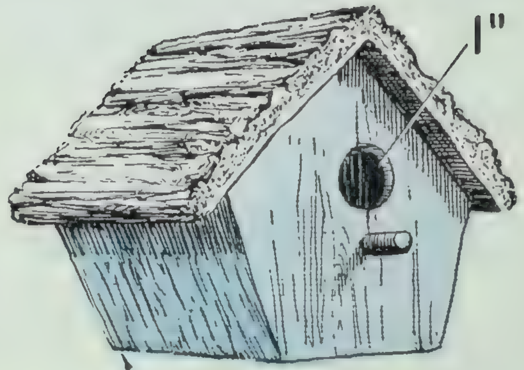
not shoot at birds; a tin can on a post makes a better target.

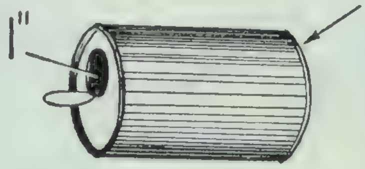
3. Set up a bird bath in your garden or school yard. The bath can be made of concrete, or you may use a shallow pan. Add fresh water daily.

4. Build a bird house and erect it in a suitable place. Before starting, draw a plan of a house designed for a certain kind of bird. Consult the table on page 120 and follow the dimensions carefully. A useful booklet, called *Bird Houses and Their Occupants,* may be obtained free of charge from the Department of Northern Affairs and National Resources, Ottawa. *One copy should be enough for your classroom.* If you paint your bird house, avoid bright colors. Wren, robin, and martin houses may be placed near your house; blue-

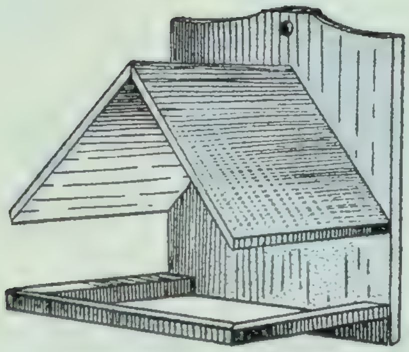


bluebird house





wren houses



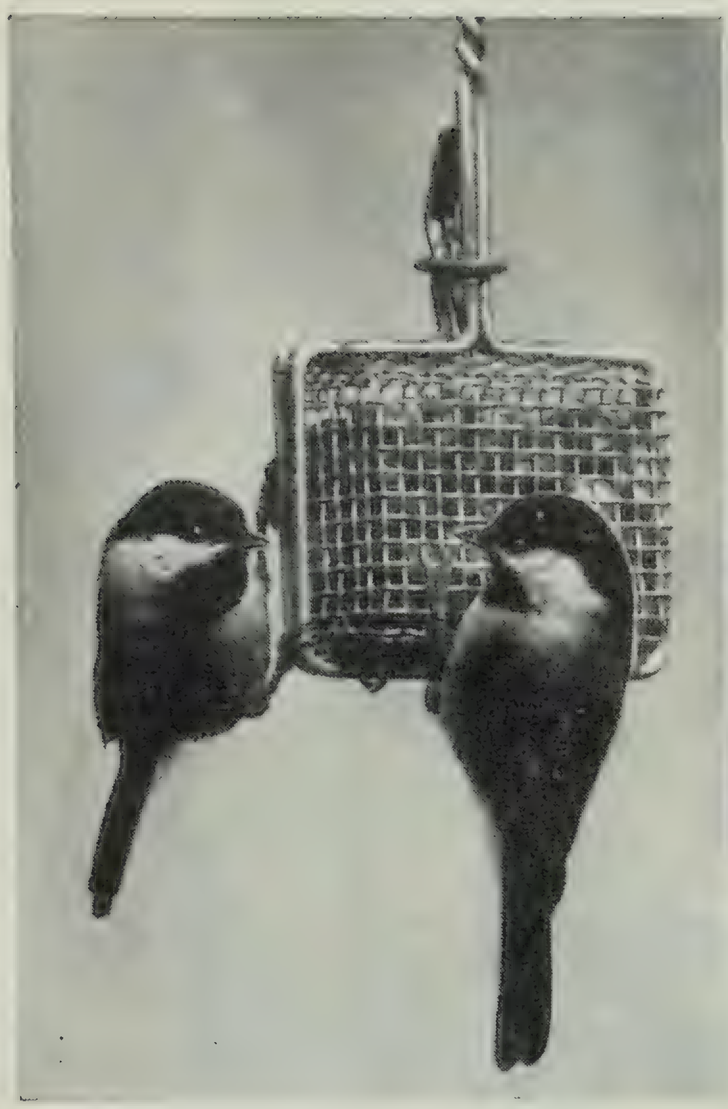
nest shelf for robin

bird bath

Some ways of helping birds. Different kinds of birds like different kinds of houses. For wrens and bluebird houses be sure that the entry hole is of the proper size. Why?

BIRD HOUSE DIMENSIONS

	Floor	Height	Entrance from Floor	Diameter Entrance	Height from Ground
House Wren	4"x 4"	6"- 8"	4"- 6"	1"	6'-10'
Tree Swallow	5"x 5"	6"	1"- 6"	1½"	6'-15'
Bluebird	5"x 5"	8"	6"	1½"	5'-10'
Crested Flycatcher	6"x 6"	8"-10"	6"	2"	8'-20'
Chickadee	4"x 4"	8"-10"	8"	1⅛"	6'-15'
Flicker	7"x 7"	16"-18"	16"	2½"	6'-20'
Screech Owl	8"x 8"	12"-15"	12"	3"	10'-20'
Sparrow Hawk	8"x 8"	12"-15"	12"	3"	10'-20'



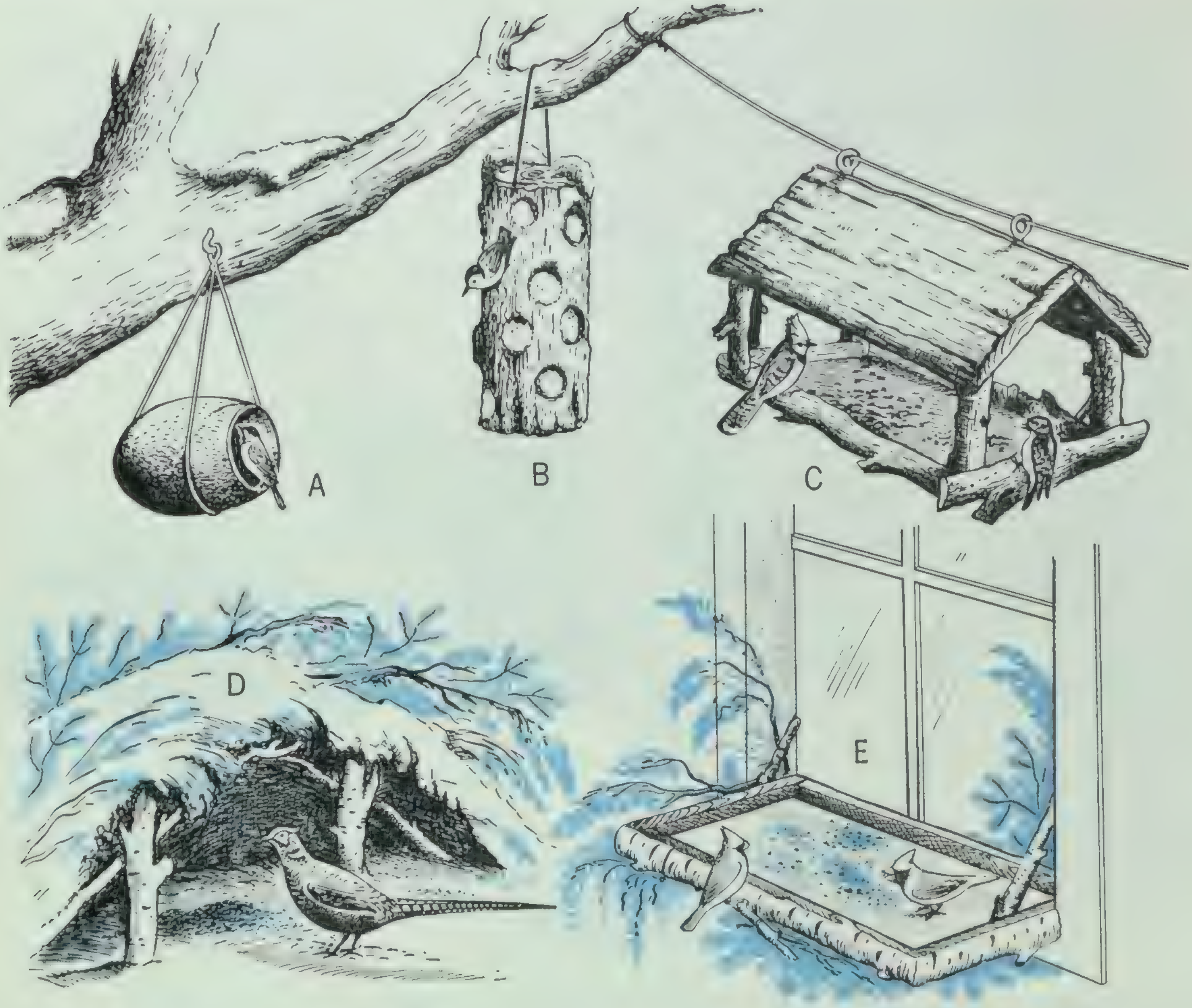
Left: Chickadees enjoying a meal of peanuts at a soap-dish feeder. Above: A white-breasted nuthatch and a downy woodpecker on a birch stump that is used as a suet log. (Left, Helen A. Baker photo; above, Hugh Halliday photo)

birds prefer to live some distance away from us.

5. Set up a bird-feeding station in the fall and maintain it all winter. A number of types of stations are shown on page 122. Game birds should be fed at some distance from your house, but most others can be attracted close to dwellings. Most winter birds like sunflower seeds, grain, suet, raisins, peanuts, and meat scraps. These may be placed on any of the tray feeders, where blue jays, cardinals, juncos, grosbeaks, waxwings, and chickadees will find them. Downy and hairy woodpeckers, and nuthatches will eat from a suet log like the one shown in the drawing on page 122 and in the photograph at the right, above. Large pieces of suet may also be hung from the branches of trees, tied or wired to a tree or post, or placed in a soap-dish feeder.

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. In what ways are birds beneficial to farmers and gardeners?
2. "A hawk is worth $30.00 or more to the farmer." Explain this statement.
3. Tell three ways in which we can help to conserve birds.



Five types of winter bird-feeding stations: A, a chickadee looking for sunflower seeds in a coconut shell; B, a nuthatch at a suet log; C, a blue jay and a downy woodpecker at a trolley feeder; D, a pheasant enjoying grain at a shelter made of evergreen boughs; E, cardinals eating seeds at a window tray feeder. Could you make one or more of these feeding stations?

Note: Not all the birds shown in this illustration are common in all areas. For example, cardinals are not prairie birds. What winter birds are common in your locality?

HOW YOU CAN BECOME A CONSERVATIONIST

When man changes his environment for modern living, as he does in building large cities, and clearing forests and ploughing prairies to prepare land for agriculture, he should not completely destroy the good things that were present in the natural environment. For example, he should conserve some of the woods and streams as parks and beauty spots, and he should protect many kinds of wildlife, such as interesting mammals, song and game birds, and wild flowers, so that everyone may continue to enjoy them. By conserving streams, forests, and wildlife for recreation, we can make life more interesting and enjoyable for everyone in our community.

Conservation is the responsibility of everyone. We must wisely use the natural resources that we have today so that future generations of people may continue to use and to enjoy them.

Conservation is the concern of young people as well as of adults. Here are eight ways in which *you* can help to conserve our wildlife resources.

1. Do not needlessly or thoughtlessly injure or destroy any living thing.
2. Obey game laws and fishing regulations.
3. Do not molest or needlessly destroy the habitats and nests of wildlife.
4. Enjoy wild flowers in their natural setting, but refrain from picking them.
5. Provide suitable habitats for wildlife – by planting windbreaks and woodlots, building bird houses and feeding stations, and restoring ponds and marshes.
6. Learn to build safe campfires, and always completely extinguish your campfire before leaving it.
7. Give every animal a fair trial. In deciding whether an animal is useful or harmful, find out its place in the balance of nature.
8. Learn all you can about wildlife, and share your knowledge with others.

WHAT HAVE YOU LEARNED?

IMPORTANT SCIENCE IDEAS AND UNDERSTANDINGS

A

1. Wildlife provides us with furs, food, and recreation, and aids us in controlling weeds, insect pests, and destructive rodents.
2. The depletion of wildlife has been caused chiefly by excessive hunting and by destroying the habitats of wild animals and plants.
3. In an area unchanged by man, a natural balance exists among the various kinds of living things that inhabit the area.

4. When man destroys wildlife or changes its habitats, he upsets the balance of nature.

5. Sometimes, species of animals brought from other countries become pests because they lack natural enemies in our country.

6. Governments help to conserve wildlife by enforcing game laws, by restocking some areas, and by setting aside large natural parks and game preserves.

7. Farmers and lumbermen can aid wildlife by protecting and restoring its habitats.

8. We can conserve wild flowers by protecting their habitats and refraining from picking them.

9. The conservation of wildlife is the responsibility of every citizen.

(a) The foregoing sentences are all true statements of important science ideas and understandings. Read and discuss them carefully as a review of this chapter.

(b) The following sentences describe situations in which some of these ideas apply. To test your ability to apply ideas to actual situations, match the sentences in A with situations in B to which they apply.

B

1. Jane Brown watched a flicker making its nesting hole in a dead tree. Several days later, she saw that a pair of starlings had taken the hole for themselves.

2. Around the base of a tree in which there was an owl's nest, some pupils found dozens of skulls of field mice.

3. Stella Veres visited a fish hatchery, where she saw thousands of young trout that were nearly large enough to be released in clear streams.

4. A forest fire burned off an area near Mr. Patton's cottage. The next year there were no wild flowers to be found there.

5. In a magazine article, Peter Stevens saw an aerial photograph of the nesting grounds of the rare whooping crane in Wood Buffalo National Park, in the Northwest Territories.

6. Walter Emery was studying some illustrations of frontier days in Saskatchewan. One painting showed men on horseback shooting bison in large numbers.

7. Mr. Dupont planted a windbreak of evergreen trees along the west side of his garden.

IMPORTANT SCIENCE TERMS

A

depletion	extinct	game preserve
conservation	food chain	bird sanctuary
predator	closed season	balance of nature
habitat	bag limit	

To show that you understand and can use the science terms listed in A, match with the sentences in B those terms that apply.

B

1. Ruth Kelly and Lillian Goodman were very interested in the passenger pigeon exhibit that they saw at the museum. The description on the exhibit stated that passenger pigeons can now be seen only in museums, but that at one time they were the most numerous birds in our country.

2. Coyotes are often beneficial because they catch the mice and gophers that eat the farmers' grain.

3. When Mark Waltman and his father went trout fishing, they knew that they would have to go where there was a clear, cool stream.

4. One Saturday in May, several boys from Mr. Kennedy's class went trout fishing. Tony Romano landed a fine black bass. "I'll have to throw it back," he said, regretfully, as he carefully removed it from the hook and released it. "We're not allowed to keep bass until July 1 this year. They are probably laying their eggs this month."

5. Earl Crosby's father was discussing deer hunting. "Each hunter is allowed to take only one deer this year. That way, there should be good hunting for all, and more deer will be left for next year."

SCIENTIFIC METHOD AND ATTITUDES

1. Walter Emery disliked snakes. Someone had told him that all snakes are harmful, so whenever he saw a snake he killed it. However, in a conservation book, he read that garter snakes and most other kinds of snakes are beneficial.

(*a*) If Walter made a practice of *basing his thinking on facts,* how might he have solved the problem of whether garter snakes are useful or harmful?

(*b*) Assuming that his investigations showed that garter snakes are beneficial, how would you be able to tell whether Walter was open-minded?

2. Early in the present century, the trumpeter swan was near the brink of extinction. Some people said that the few remaining specimens should be captured and mounted in museums so that everyone would have a chance to see this large bird. Scientists disagreed with this idea, pointing out that if the birds and their habitats were protected, the birds might be conserved. This protection was given, and the number of trumpeter swans has increased from year to year.

Recently, a similar problem has arisen with the tallest Canadian bird, the whooping crane. For several years there have been only about thirty of these rare birds. No one is permitted to molest these white waders, either on their nesting grounds in Northern Canada, or in their winter resting grounds in Texas.

(*a*) Do you agree with the people who think that rare animals should be killed and placed in museums so that everyone can see them? Why?

(*b*) What do you think caused the depletion of the trumpeter swans? Apply what you have learned to show that the scientists' suggestions were good ones.

(*c*) Do you think that it is worth-while to set aside sanctuaries for the whooping cranes? Why?

(*d*) The question of whether or not the "whoopers" will survive may take many years to answer. Watch for the yearly report on the number of "whoopers" that migrate south.

The common loon lives on lonely distant lakes far from the haunts of man. Its eerie, laughing call is one of the wildest sounds in nature. This remarkable bird should be protected.

Sperry Gyroscope Company

What unseen force is present here,
That on his way the traveller leads?
Mysterious power that serves our needs!

CHAPTER 3

CHAPTER 3

HOW MAGNETS BEHAVE

For many centuries, travellers and explorers have used compasses to help them find their way across land and sea. How does the compass help them? Why does a compass needle point toward the north? What are the properties of a magnet? How is the earth like a magnet? What is the field of force about a magnet? How can one magnet be used to make another?

HAVE YOU EVER BEEN LOST in the woods or on the wide open plains at night, not knowing which way to go to get home? Many people have had such nerve-racking experiences. In a situation of this kind, as you know, you can, if the sky is clear and the stars are shining, locate the position of the North Star and then determine the direction you should travel to reach your camp or your home. For thousands of years, the stars have been an aid to navigation.

But if the sky is overcast and no stars can be seen, how then can you find the right direction to go? Some means other than the stars is needed under these conditions.

Long ago, people learned that if a *magnet* made of iron was set on a cork disk or a small piece of wood floating in water, the magnet would turn until it pointed in a north-and-south direction. This served as a compass. Early explorers depended upon the compass to guide them over the oceans to the distant lands that they were seeking. Today, the compass still helps us to find our way on land or sea or in the air.

The needle of a compass is a small magnet suspended on a point. Before the compass was invented, direction was found by suspending a piece of *lodestone*. Lodestone is an iron ore that is naturally magnetic. Pieces of this ore are called *natural magnets*. The modern name for lodestone is *magnetite*. Deposits of magnetite are found in various parts of Canada, including the iron fields north of Lake Superior.

LEARNING ABOUT MAGNETS

Most boys and girls like to do things for themselves rather than just watch while someone else does them. In your study of magnets there will be many opportunities for you to perform experiments to find out how magnets behave. The apparatus and materials required for these experiments are not difficult to obtain. It is very important for you to learn what materials you will need and to make sure that you have them on hand when they are required.

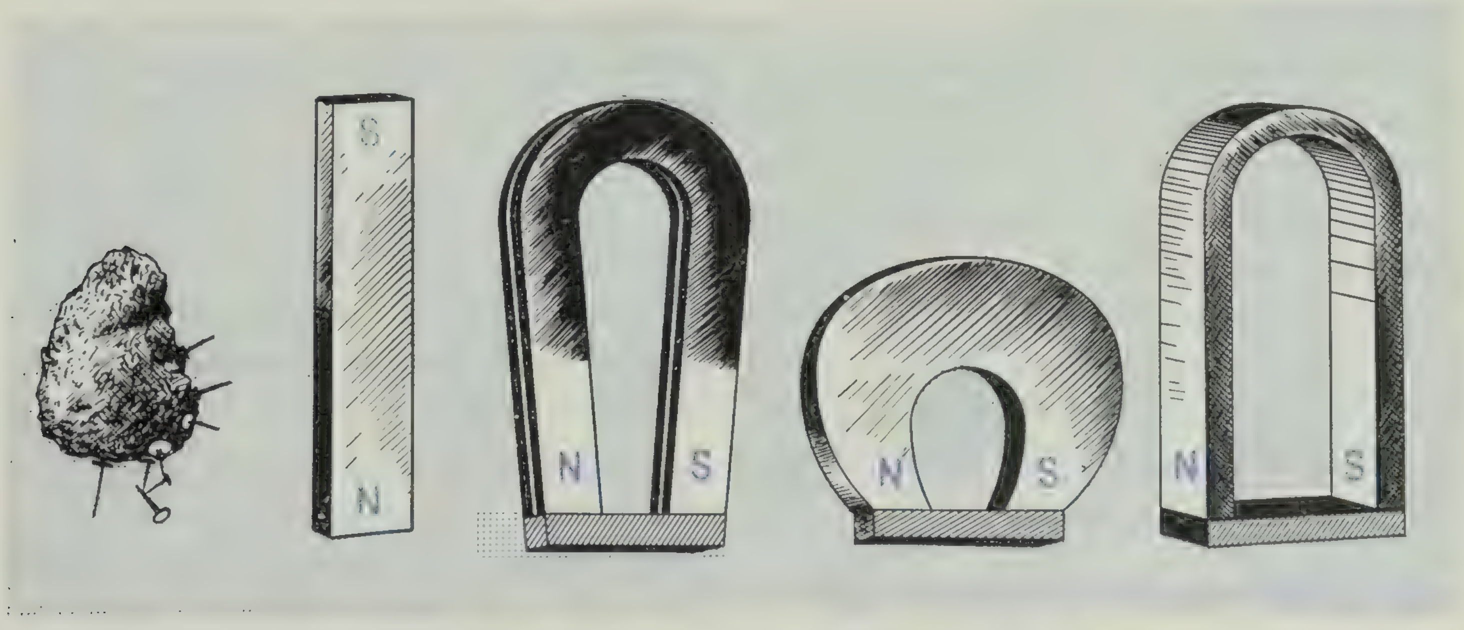
You have probably observed for yourself one property of a magnet, namely *that it has the power to attract pieces of iron and steel.* Let us perform an experiment to discover a second property.

SOMETHING TO DO

NOTE. — Magnets for this experiment may be obtained from an automobile repair shop or from certain toys, or they may be purchased from hardware stores or science equipment companies.

Suspend a magnet by means of a fine cord or thread. (If it is a horseshoe magnet, hang it with the points down; if it is a bar magnet, suspend it horizontally.) Do not suspend your magnet near any metal such as an iron desk, radiator, etc. Why? Allow it to swing freely. When it comes to rest, note the direction in which it points. Mark the end that is pointing north, and swing the magnet around again once or twice. When it comes to rest, observe whether or not the same end again points north. Can you now state another property possessed by magnets? What use do we make of this information?

ALTERNATIVE EXPERIMENT. — Suspend a magnet by placing it on a small block of wood floating in water. Then follow the procedure and make the observations suggested above.



A group of magnets. From left to right: Natural magnet (magnetite); bar magnet; horseshoe magnets; U-magnet. Notice the *keeper* or bar across the poles of the magnets at the right. What purpose does the keeper serve?

THE RIGHT WAY TO PERFORM EXPERIMENTS

When a scientist has decided to perform an experiment to help him solve a problem, he organizes his experiment in six steps. You should learn to do the same. The six steps are:

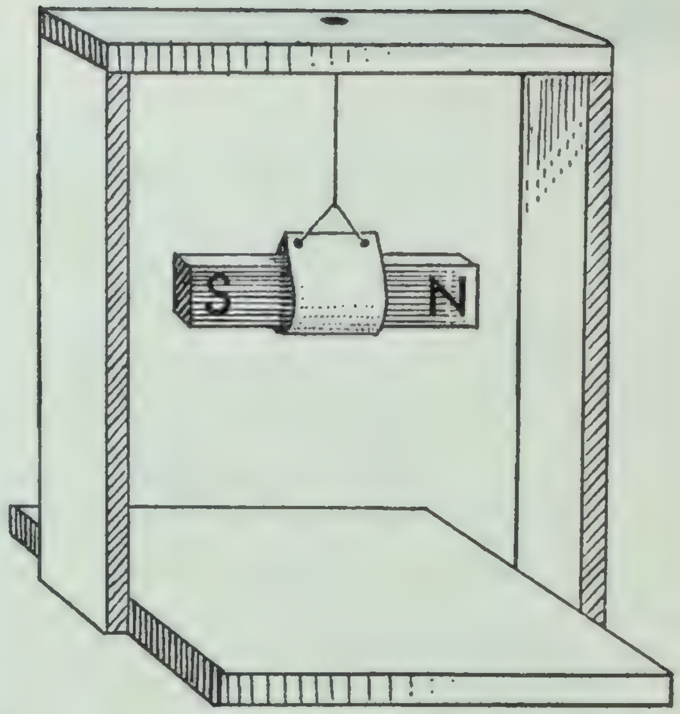
1. Have a clear idea of your *problem.*
2. Decide what *apparatus* is required.
3. Carefully plan your *method* or procedure.
4. Make careful *observations* and accurate records of results.
5. Think well in order to arrive at a true *conclusion.*
6. Try to find an *application* or use for the discoveries that you have made in your experiment.

The poles of a magnet

You learned, in the foregoing experiment, that a suspended magnet comes to rest pointing approximately north and south. The ends of the magnet are known as *poles.* The pole that always points north is the *north-seeking* or the *N pole.* The other pole is the *south-seeking* or the *S pole.* It is sometimes important to know the polarity of a magnet.

Magnetic substances

Does a magnet attract all substances or just certain ones?



A good way to suspend a magnet. The frame is made of boards. The magnet holder is a small sheet of folded paper with thread tied near its corners. Make one of these for yourself.

NOTE. — Make very sure that you obtain a magnet and use it to perform the following experiment.

SOMETHING TO DO

With a magnet, touch small pieces of wood, chalk, paper, brass, stone, nickel (a Canadian five-cent piece), copper (a one-cent piece), iron (a bolt or nut), glass, wax, steel (a sewing needle), rubber, lead, cloth, etc. The more substances you test the better. Why? What do you observe? What conclusion do you reach from your observations?

The results of your experiment, no doubt, will have shown that only a few materials are attracted by a magnet. Of these, iron and steel (a hardened form of iron) are the most important. These substances are strongly attracted. Other substances, such as nickel and cobalt, are also attracted, but not so strongly as

An experiment to find which substances are attracted by a magnet. Which of the substances shown here did you find to be magnetic? Which are not?

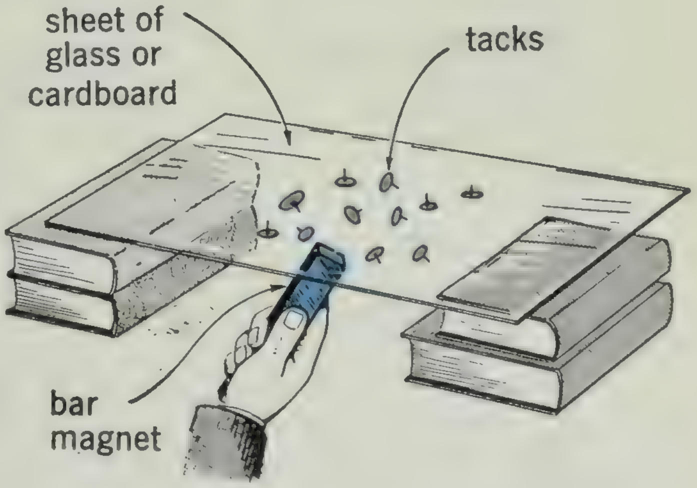
iron and steel. *Substances that are attracted by a magnet are known as magnetic substances.*

Can the force of a magnet pass through certain materials?

In your experiments with magnets, you have likely been surprised to find that you did not have to touch your magnet to iron tacks, for example, in order to attract them. If a magnet is brought close to magnetic substances, there is a tendency for such substances to move toward the magnets. This shows that the force of the magnet can travel through air. Can it travel through other substances as well?

SOMETHING TO DO

1. Support a sheet of heavy paper or cardboard on two piles of books or other supports as shown in the illustration below. Place some iron tacks on the cardboard. Move one end of the magnet around below but close to the cardboard. Do the tacks change their positions as the magnet is moved back and forth? What does this prove about the force of a magnet?



Be sure to try this experiment. Can magnetism pass through glass? How do you know?

2. Repeat this experiment using thin sheets of wood, glass, galvanized iron, copper foil, tin foil, aluminum, etc. What happens in each case?

Does the force of the magnet pass directly through different materials equally well?

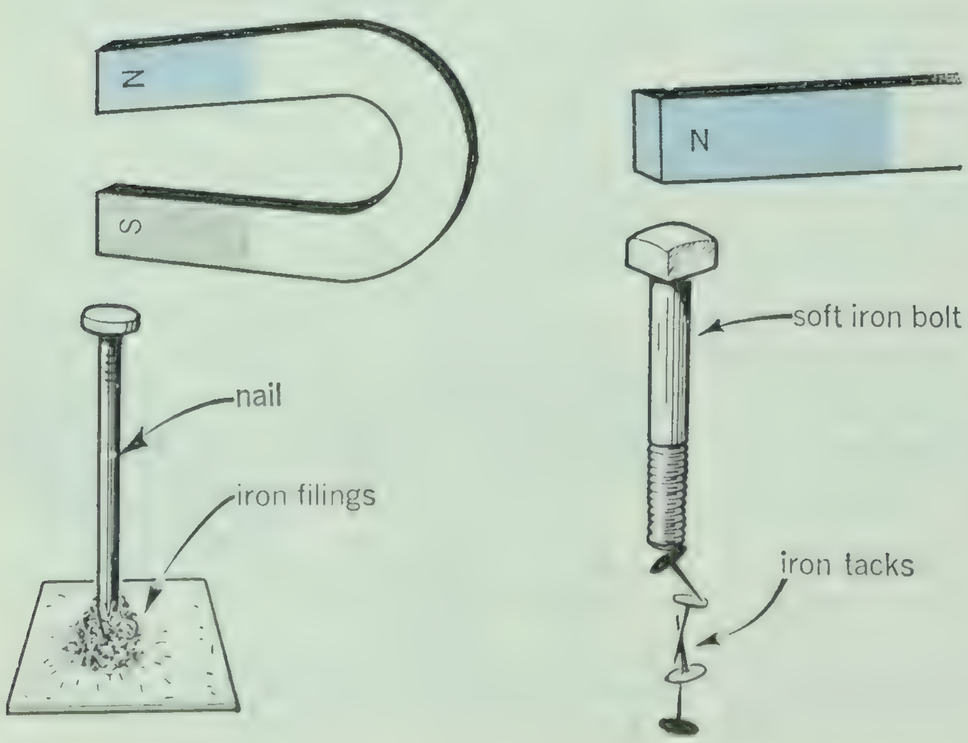
Magnetic shielding

You have seen that some materials permit magnetic force to pass through them more readily than others. When a sheet of a material prevents magnetic force from passing directly through to the other side, we say that it is a *magnetic shield*. What materials are best for magnetic shielding?

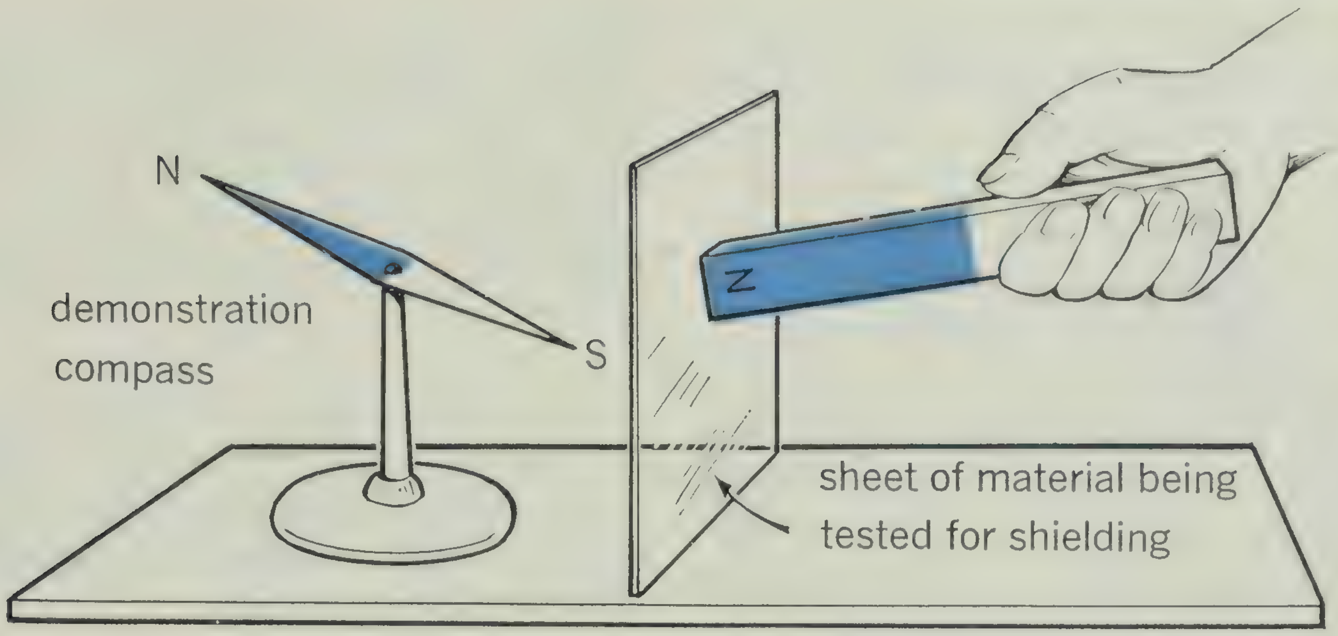
SOMETHING TO DO

Perform the two experiments shown on page 133. As you will see, they are somewhat similar to the previous experiment, but they should enable you to test more accurately sheets of various materials. In each experiment, test sheets of glass, paper, cardboard, wood, iron, steel, aluminum, etc. In doing the experiment using the demonstration compass needle, move the needle about a one-quarter turn to one side and then let go. Count the number of swings it makes before coming to rest. Repeat this with each sheet of material used. How do you account for the difference in the number of swings? What materials let the magnetic force pass directly through? Which ones did not let the magnetic force pass directly through them? Which ones would be most useful for magnetic shielding?

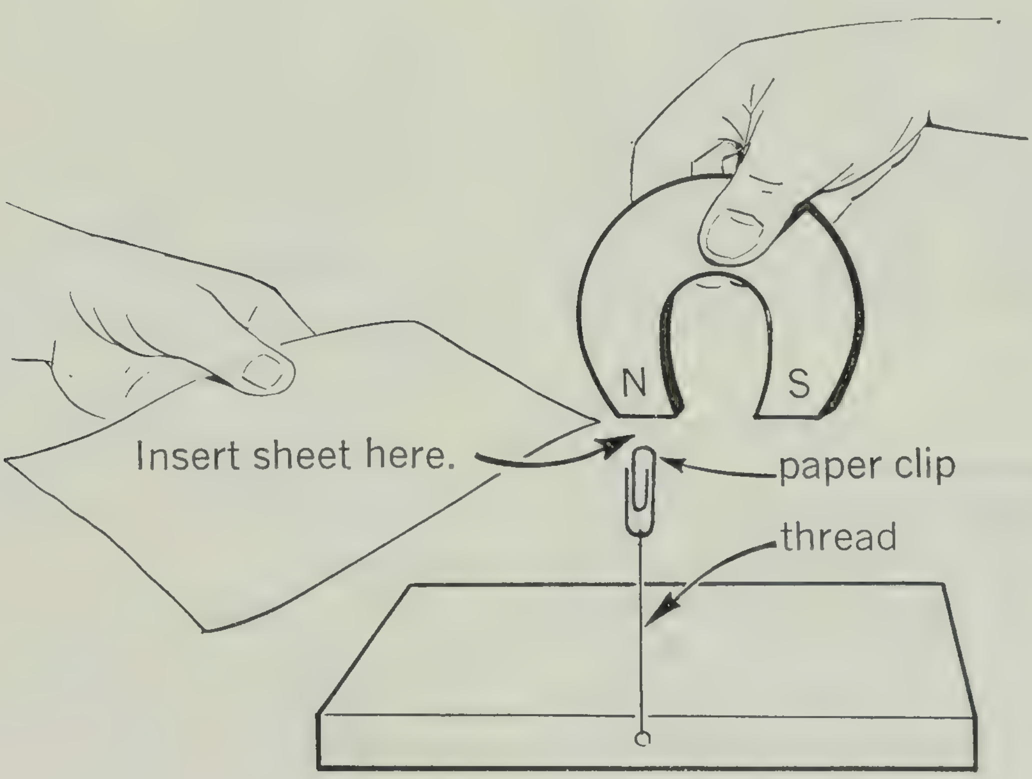
As you have seen, a sheet of a magnetic substance, such as iron and steel, does not let magnetic force pass directly through it. Therefore magnetic substances are useful in shielding against magnetism. It is thought that instead of passing *through* a sheet of magnetic substance, the magnetic force runs *along* the particles of metal forming the sheet of metal.



Try this experiment. Hold a nail or a bolt close to, but not touching, the pole of a magnet. Make the tests shown here to find out if the nail or the bolt behaves as a magnet. What happens to the tacks or the iron filings when the magnet is removed?



An experiment to demonstrate magnetic shielding, and to test the shielding effect of different materials. A demonstration compass should be used, if available, but any good compass works quite well. How can you tell whether the magnetic force passes easily through the material being tested? What happens when sheets of materials, such as iron and steel, are placed between the magnet and the compass? What materials are the best for shielding the compass from the influence of the magnet?



Here is another experiment for you to try in testing the shielding effect of various substances. Insert, one at a time, sheets of wood, glass, cardboard, tin, copper, iron, and other materials. What do you observe? Through which materials does magnetism pass freely? Which material (or materials) does it not pass through? If you wished to protect an instrument from the earth's magnetism, which material would you use? Should the instrument be completely surrounded by this material?

If you own a watch, never put it near a strong magnet. Why? A watch usually has steel parts in its mechanism. If these parts become magnetized, the accuracy of the watch will be affected. Often the metal case of a watch serves as a shielding against magnetic force.

The pick-up attachment of a high fidelity record player must be shielded from the magnetic force of the electric motor. This is done by enclosing the motor in a magnetic material.

Magnetic substances are used as shielding in many other places employing powerful magnets.

The law of magnetic attraction and repulsion

Usually we think of a magnet as a piece of steel that will attract other pieces of steel or iron. It is also true, however, that a magnet will sometimes "chase away" or *repel* another magnet. Under what conditions will this happen? Solve this problem by performing the following experiment:

SOMETHING TO DO

Problem. – What happens when like and unlike poles of magnets are brought near each other? Two like poles are two S (south-seeking) or two N (north-seeking) poles. Two unlike magnetic poles are an S pole and an N pole.

Apparatus and Material. – Two magnets and the apparatus to suspend one of them.

Method. – Mark the N poles of both magnets. Suspend one magnet. Make tests as suggested in the problem.

Observation. – What occurs when the N poles of the two magnets are held near each other? What happens when the two S poles are brought near each other? When the N pole and the S pole are held close to each other?

Conclusion. – What do like poles and unlike poles of magnets do to one another?

You no doubt found that *like poles of magnets repel one another and unlike poles of magnets attract one another.* This is *the law of magnetic attraction and repulsion.*

KEEP A CAREFUL RECORD OF ALL EXPERIMENTS

Write your record in your own words. Make your descriptions sufficiently complete so that all details of the experiment will be called to mind when you read your notes later. Remember to arrange your report under these headings:

Problem. – What you wanted to find out.

Apparatus and Material. – What you used.

Method. – What you did.

Observation. – What you saw.

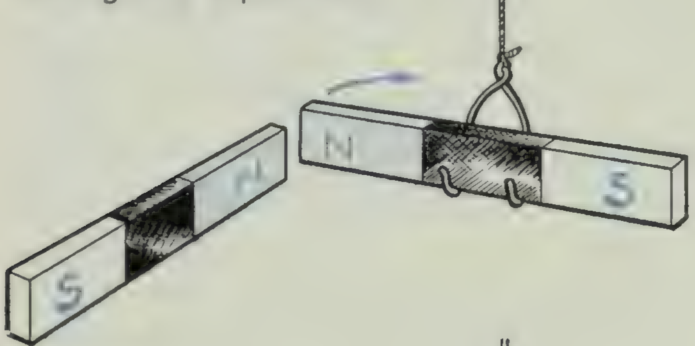
Conclusion. – What you learned.

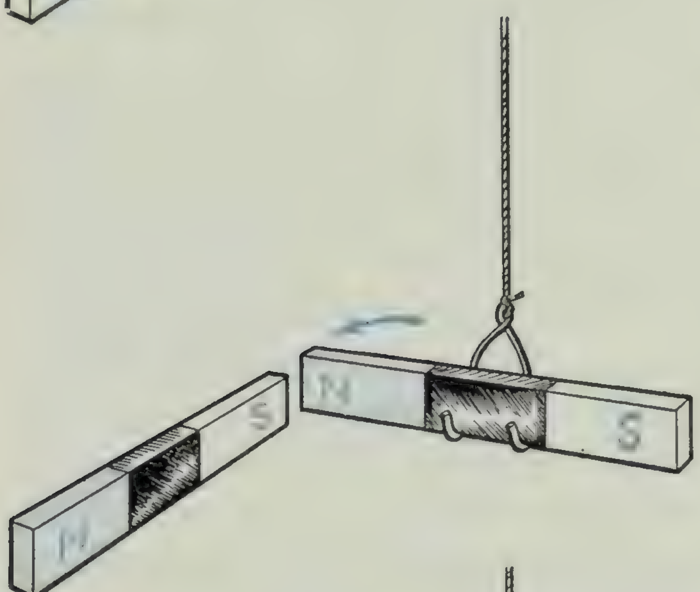
Notice that the conclusion is an answer to the question asked or suggested in the statement of the problem.

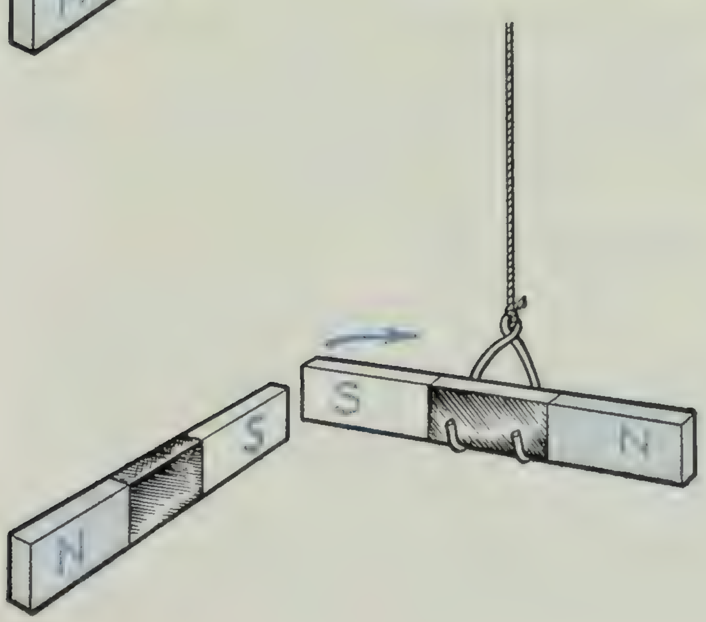
A carefully drawn and neatly labelled diagram of the apparatus is useful in recording your experiment.

Alternative Experiment. – The preceding experiment may also be performed by using a bar magnet and a compass, if the bar magnet is not too strong, or if it is held several inches away from the compass needle.

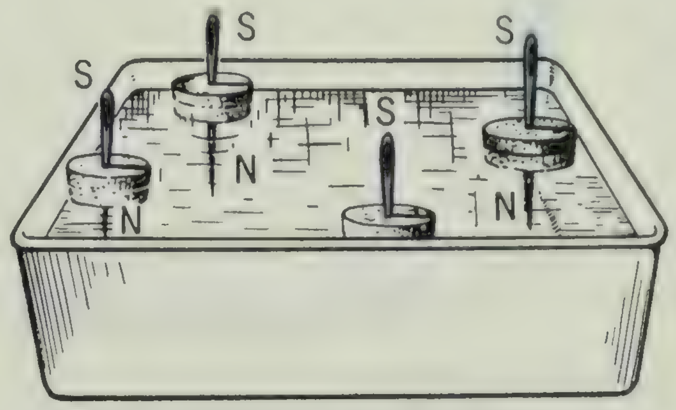
Which poles of magnets attract each other and which repel? Be sure to find this out for yourself by performing this experiment.







Remember that the needle in a compass is a magnet. The N pole of the compass needle is often colored.



Magnetize four darning needles so as to make in each case an N pole at the point and an S pole at the eye. Push each through a cork disk. Float the disks close together in a pan of water: (1) with all S poles up; (2) with all N poles up; (3) with two S poles and two N poles up. What do you observe in each case? Account for the behavior of the cork disks.

How to test for magnetism

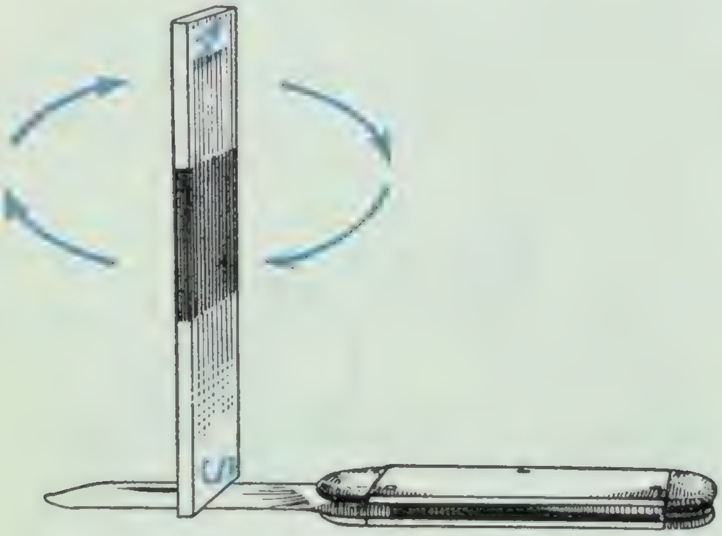
We observed in the previous experiment that one pole of a magnet is attracted and the other pole repelled by the pole of another magnet. Which do you think would be the more reliable test for magnetism, *attraction* or *repulsion*?

SOMETHING TO DO

Problem. – How can you tell whether a piece of iron is magnetized?

Method. – To determine whether a piece of iron is magnetized:

(*a*) Present one end of the piece of iron being tested first to one end and then to the other end of a suspended magnet (or a compass needle). If there is attraction at one pole of the suspended magnet and repulsion at the other, the iron is magnetized. But, if there is attraction at each pole of the magnet, the iron is not magnetized.



Magnetizing a knife blade. What pole will be produced at the point of the knife in this case?

(*b*) Repeat the experiment using a bar magnet held in your hand. Bring the N pole of the magnet close to one end and then to the other end of a different piece of iron. What do you observe? Did the N pole of the magnet attract both ends of the piece of iron? Was the piece of iron a magnet? Why?

If you tested a short length of soft iron wire or other unmagnetized piece of soft iron, you no doubt found that both ends of it were attracted by a magnet. Therefore, attraction is not proof that the substance attracted is a magnet. However, if the same end of a bar magnet is brought close first to one end and then to the other end of the substance being tested, and you find in one case that there is repulsion, the substance is a magnet. A substance can be considered to be a magnet only if it has the ability to repel another magnet or to be repelled by one. Therefore, *the test for magnetism is repulsion.*

State the law that applies above (see page 134).

How to make a magnet

The compass needles and the bar and horseshoe magnets with which you have been experimenting are made of steel. Steel is hard, and magnets made of steel remain magnetized for a long time. For this reason, steel magnets are spoken of as *permanent magnets.* In comparison with steel, iron is soft and quickly loses its magnetism. Magnets made of soft iron are *temporary magnets.* A simple method of making permanent magnets is described in the experiments that follow. Be sure to make several of them.

Although most magnets are made of iron and steel, there are some magnets in which other metals are used as well. Certain materials are made by melting together two or more metals such as iron and nickel. These mixtures of metals are called *alloys.* Some alloys are magnetic, and others are not. One very important alloy is called *alnico.* The name alnico is formed from the first two letters of the three metals that are melted together; *al*uminum, *ni*ckel, and *co*balt. Magnets made of alnico are very strong. Some of them will lift 4000 times their own weight!

SOMETHING TO DO

1. Obtain a steel knitting needle or a large sewing needle. Test it to see if it is a magnet. Then stroke it several times with one pole of a magnet. Be careful always to stroke it in the same direction. To do this, hold the magnet so that it touches one end of the needle,

and move it along the needle to the other end; then lift it away from the needle back to the first end, and stroke the needle as before. Repeat the stroking several times. Test the needle again for magnetism. What do you find?

Other methods of making magnets

You have already learned how to make a magnet by stroking a piece of iron or steel with a pole of a permanent magnet. Is it possible to make a magnet out of a magnetic substance without actually touching it? You can find the answer to this question yourself by performing the experiment outlined below.

SOMETHING TO DO

1. Obtain a soft iron bolt or a nail. Test it with a compass to make sure that it is not a magnet. (Remember, the test for magnetism is *repulsion.*) Touch one end of the bolt to a pile of iron tacks or iron filings, then raise the bolt. What happens?
2. Next hold one pole of a bar magnet near, but *not touching,* the upper end of the bolt and find out if the bolt will now pick up the iron filings or the tacks.
3. Now move the permanent magnet well away from the bolt. What happens?
4. Repeat this experiment several times.
5. Repeat the experiment again, using a horse-shoe magnet instead of a bar magnet. Are your observations the same as before?

How do you account for the results that you obtained?

Your experiment should prove that it is possible to make a magnetic substance into a magnet without actually touching or stroking it with a magnet. The method you used in your experiment to magnetize the bolt or the nail is known as the *inductive method.* Were the magnets that you made in this way permanent or temporary? How do you know?

Another widely-used method of making magnets is known as the *electromagnetic method.* This method requires the use of electricity. It is described on page 170.

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. What is a magnet? State two properties of magnets.
2. Where are the poles of a magnet located? What names are given to the poles? Why?
3. How would you perform an experiment to demonstrate the law of magnetic attraction and repulsion? Illustrate with drawings.
4. How would you find the N pole of an unmarked magnet, by using a marked magnet? State the law that you must know in order to do this.
5. How would you discover whether a needle is magnetized?
6. What is meant by a magnetic substance? Name four magnetic substances and four non-magnetic substances.

7. One day in class, Stella Veres made the following statement: "A magnet does not attract glass, but it attracts through glass." Devise and carry out an experiment to test the truth of Stella's statement.

8. What is meant by magnetic shielding?

WHAT IS MAGNETISM?

The pupils in Mr. Kennedy's class had performed a number of the experiments with magnets that you have been doing. They had learned something about the way magnets behave, but they were still curious to know more about them.

"Why is it that iron and steel can be made into magnets, while copper and silver cannot?" asked Ruth Kelly.

"Are you sure that is right, Ruth?" remarked Janet Brown.

"Yes, I'm quite sure. I was able to magnetize a piece of steel wire by stroking it in one direction with the N pole of a bar magnet. However, when I tried the same experiment using a piece of copper wire instead of the steel wire, the copper did not become magnetized."

"Well then, steel must have something in it that isn't present in copper," Peter Stevens suggested.

"That's right," said Earl Crosby. "Steel and copper are different. Steel is much harder than copper. Maybe that's why steel can be magnetized while copper cannot be."

Peter offered another suggestion: "Perhaps iron and steel just naturally contain magnetism, and copper and silver do not. I remember that Mr. Kennedy told us about certain iron ore deposits that show magnetic properties. Pieces of this ore as found in nature behave as magnets."

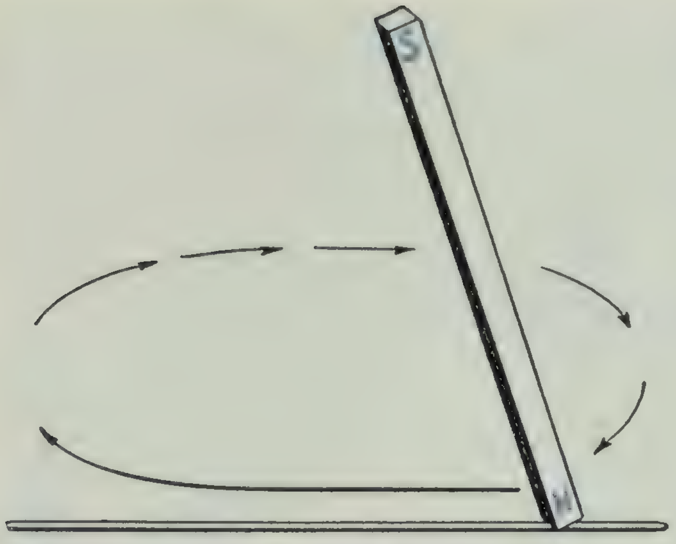
After further discussion, the pupils finally decided to perform an experiment as suggested by Mr. Kennedy to test the truth of Peter's explanation of the problem that they were trying to solve.

SOMETHING TO DO

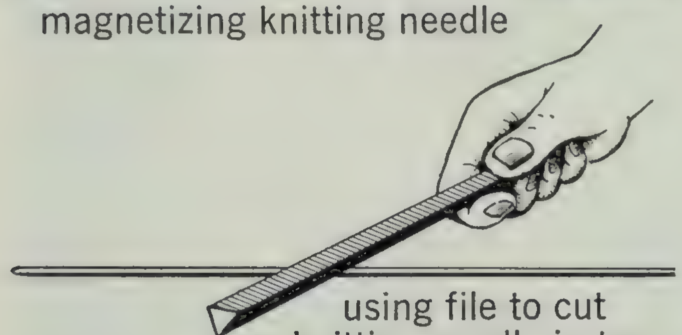
Problem. — Is each part of a magnetized steel wire a magnet?

Apparatus and Material. — A fine *steel* wire about one foot in length (a knitting needle will do); a bar magnet: a compass; a three-cornered file.

Method and Observations. — (1) Test the wire for magnetism. (2) Magnetize the steel wire in the way you learned on page 136. (3) Test both ends of the wire to determine the polarity of each by presenting each end in turn to the poles of the compass needle. Put a small piece of paper over the N end. (4) Using the file, sever the wire at the middle. Now test each half for magnetism. What do you observe? Mark each N pole with a small piece of paper. (5) Again using the file, sever each half of the wire at its middle point. Now test each quarter of



magnetizing knitting needle



using file to cut
knitting needle in two

using compass to test polarity
of cut ends of needle

From top to bottom are the three steps in an experiment to find if each part of a magnetized steel wire is a magnet. Be sure to perform the experiment yourself to find the answer.

the wire to discover if it is a magnet. What do you find?

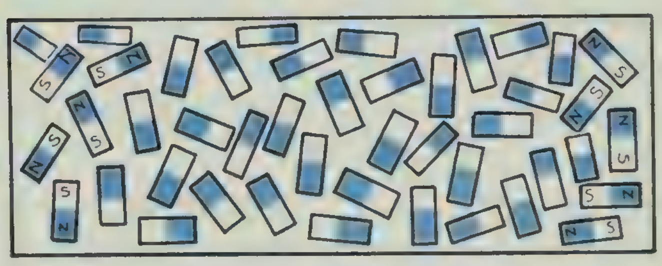
Assuming that you could cut the wire into eighths, sixteenths, etc., would you expect to find that each part was a magnet with an N and an S pole?

Conclusion. – Answer the question asked in the problem.

After the pupils had completed the experiment, Mr. Kennedy discussed their observations with them. He then commented as follows:

"You have found out by experiment that each part of a magnetized steel wire or steel knitting needle is a magnet. If you could divide and subdivide the wire until you reached the smallest possible length of iron – a *molecule* of iron – what would you expect to find? You would expect to find that each molecule is a magnet, with an N and an S pole. Scientists believe this to be true. They tell us that *each molecule of a magnetic substance is a magnet.*"

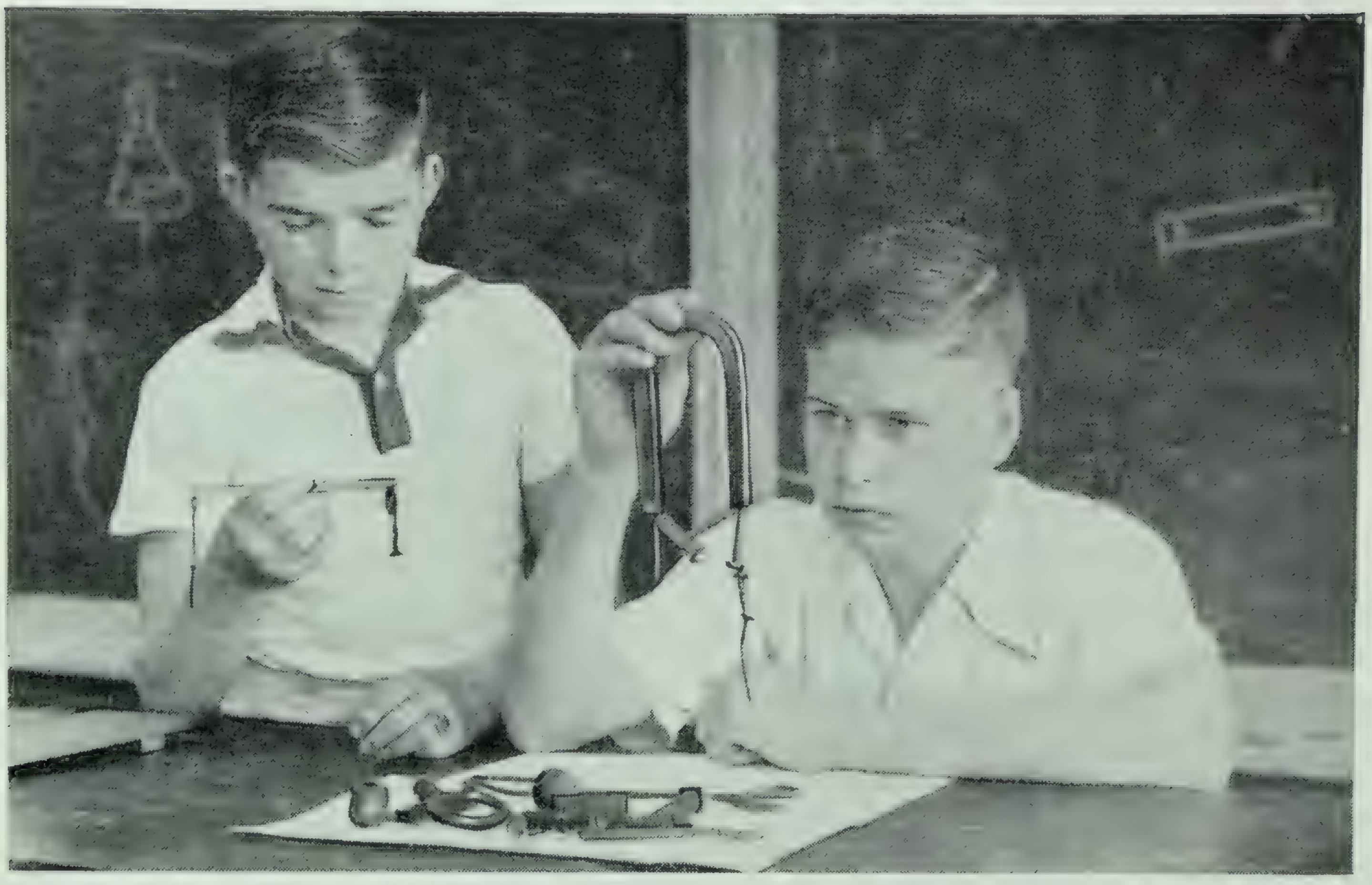
In an unmagnetized piece of iron or steel, the molecules are arranged in haphazard fashion so that the magnetic force is not evident (see the top drawing below). When the iron or steel is stroked in one direction with one pole of a magnet, the magnetic force of the magnet causes the



unmagnetized steel

magnetized steel

Study these illustrations to see how magnetized steel differs from unmagnetized steel. Explain why a steel knitting needle can be magnetized by stroking it with a bar magnet.

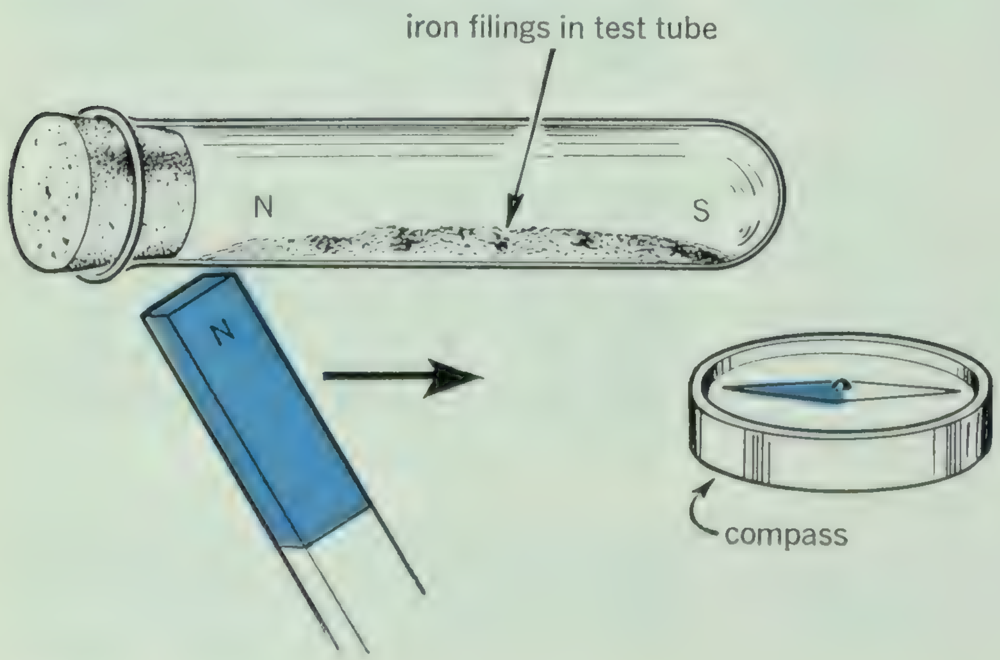


Experimenting with magnets to find out how they behave. When the picture was taken, the boys were testing various substances to discover which of them are magnetic.

molecules to line up in regular order with all the N poles facing in one direction and all the S poles in the opposite (see bottom right drawing, page 139). The material then behaves as a magnet. It has been magnetized.

The nature of magnetism

In order to obtain additional first-hand information about magnetism and the way in which magnets behave, you should perform the following experiments.



Another experiment to discover the nature of magnetism. Be sure to try this for yourself. What happens?

SOMETHING TO DO

1. Perform an experiment to find out how small pieces of iron can be made into a magnet.

Fill a test tube about one-quarter full of iron filings. Stopper the mouth. Holding the test tube in a horizontal position, shake it until the filings are evenly distributed in a haphazard manner throughout the length of the tube. Now test, as follows:

(*a*) By holding a compass close to the end of the test tube, determine whether the iron filings behave as a magnet.

(*b*) Next, using one end of a bar magnet, stroke the underside of the test tube a number of times, being careful to stroke in the same direction each time, and to keep the test tube steady. What do you observe? Are the filings now lined up lengthwise in the test tube in an orderly fashion? Again test with your compass to see if the iron filings now behave as a magnet.

(*c*) Shake the test tube so as to disarrange the filings and repeat parts (*a*) and (*b*) of the experiment. What do you observe?

Account for the results of your tests, keeping in mind what you learned in the preceding section about the nature of magnetism.

2. Perform an experiment to find out how heating a magnet affects its magnetism.

Magnetize a large sewing needle or a darning needle, using a bar magnet. With the aid of a compass test the needle for magnetism. Now heat the needle until it is red hot. After allowing it to cool, test it again to find out if it is as strong a magnet after having been heated as it was before.

On the basis of your observations what do you conclude about the effect of heat on magnetism? How do you account for any changes observed?

3. Perform an experiment to find out if the strength of a magnet is affected by a sudden jolt or vibration.

(*a*) Magnetize a steel knitting needle. Test to see about how many iron filings it will pick up, then wipe off the filings.

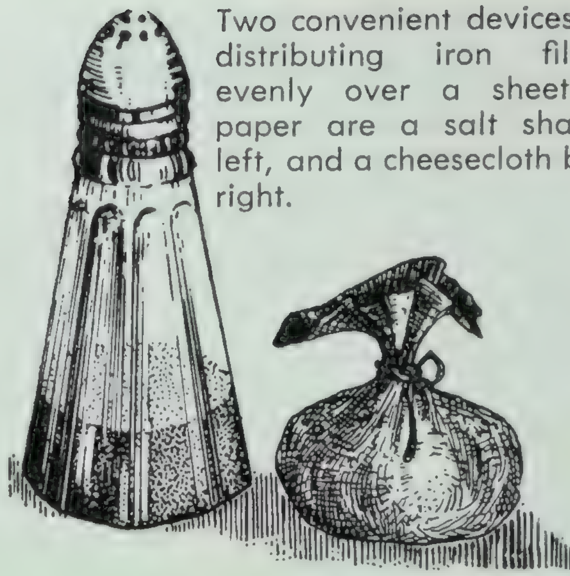
(*b*) Strike the needle sharply against something solid. Test to see how many filings it will pick up now. What do you observe? Wipe off the filings again.

(*c*) Repeat part (*b*) several times. With each succeeding jar does the needle pick up fewer filings? What do you conclude? Try to explain your results, keeping in mind the theory that each molecule of a magnetic substance is a magnet.

Your results in all three of these experiments can be explained in the same way. You need to remember three things: (1) Each small particle or molecule of a magnetic substance is a magnet. (2) Stroking a steel needle or a glass tube containing iron filings with a magnet, lines these little magnets up in regular order with their N-poles pointing toward one end and their S-poles pointing toward the other end. When this happens, the needle or the tube of iron filings becomes a magnet. (3) Shaking the tube, jarring the needle, or intensely heating the needle causes the tiny particles or the molecules to be disarranged in haphazard fashion. Under these conditions a magnet loses some or all of its magnetism.

The magnetic field about a magnet

You have learned by your work with magnets that the poles of a magnet are at its ends. You will recall that when you used a bar magnet to magnetize your knife blade or a sewing needle, you stroked the object to be magnetized in one direction, using only one pole of the magnet. You have reason to believe, therefore, that the force of the magnet is concentrated at the poles. Is there a magnetic force along the sides of a magnet also?

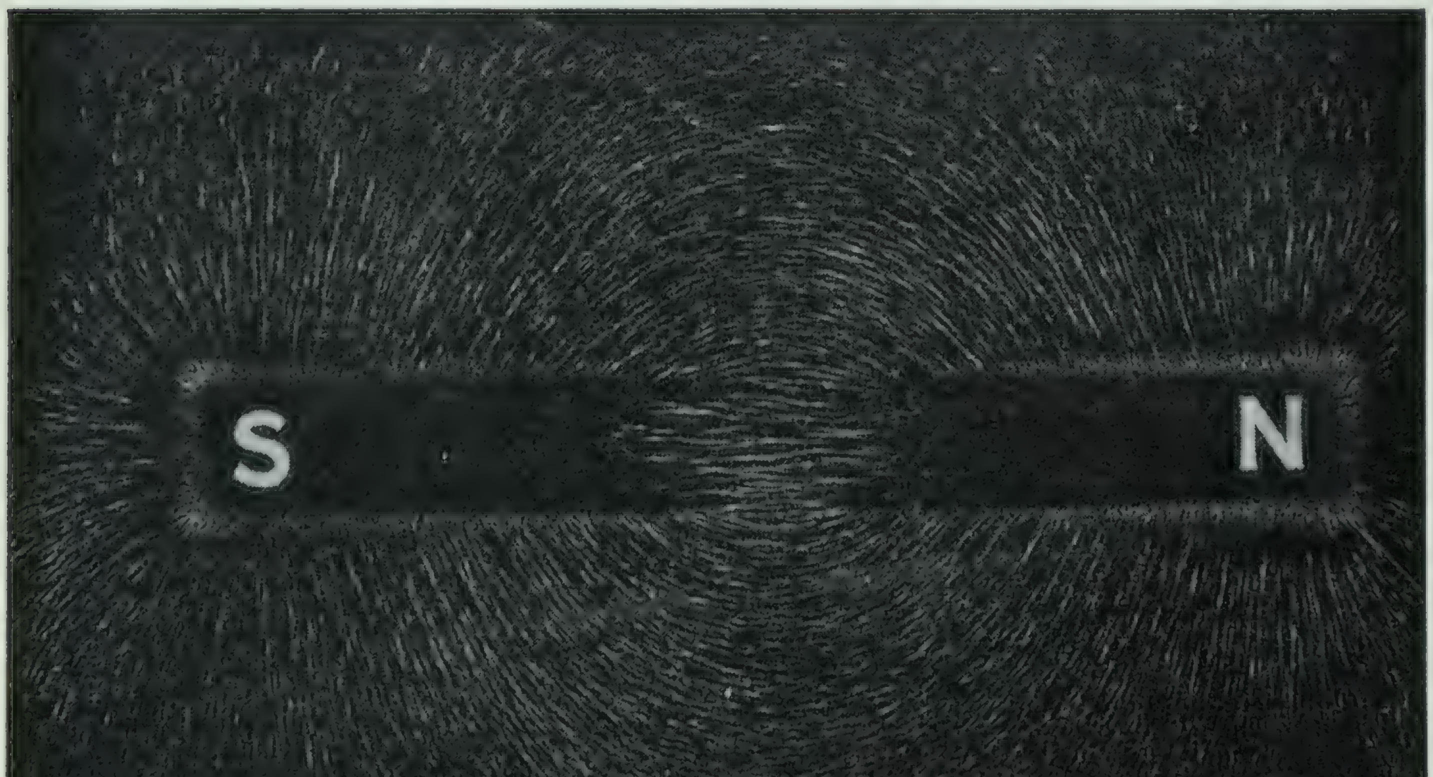


Two convenient devices for distributing iron filings evenly over a sheet of paper are a salt shaker, left, and a cheesecloth bag, right.

SOMETHING TO DO

1. Try holding a magnet at different distances from iron tacks or other magnetic substances. Do the sides of the magnet attract as well as the ends?

2. Explore the space around a bar magnet with a compass. How far away from the magnet can you hold the compass and still detect the magnetic force along the side and at the end?



Here you see the results of an experiment to find how the magnetic lines of force are arranged about a bar magnet. The iron filings that you use in your experiment arrange themselves along the lines of force and so give you a picture of the field of force.

The space around a magnet where it can exert an influence on other pieces of steel or iron is called its *magnetic field*. What is the nature of this field?

SOMETHING TO DO

1. Support a small sheet of glass over a bar magnet. Carefully sprinkle fine, dry iron filings evenly over the glass. Tap the glass gently with a pencil until the filings form a distinct pattern. Notice how the filings arrange themselves. (Iron filings can be obtained at a machine shop or hardware store, or you can make some by filing a soft iron bolt or by cutting a steel wool pad into fine bits.) Observe how some of the lines formed by the filings continue from one pole to the other.
2. Repeat the experiment using white paper or cardboard instead of glass.
3. Repeat the experiment again, this time using waxed paper. After the filings have been arranged to show the lines of force, warm the paper gently. This will cause the filings to sink into the wax and remain there to make a permanent record of the magnetic field.

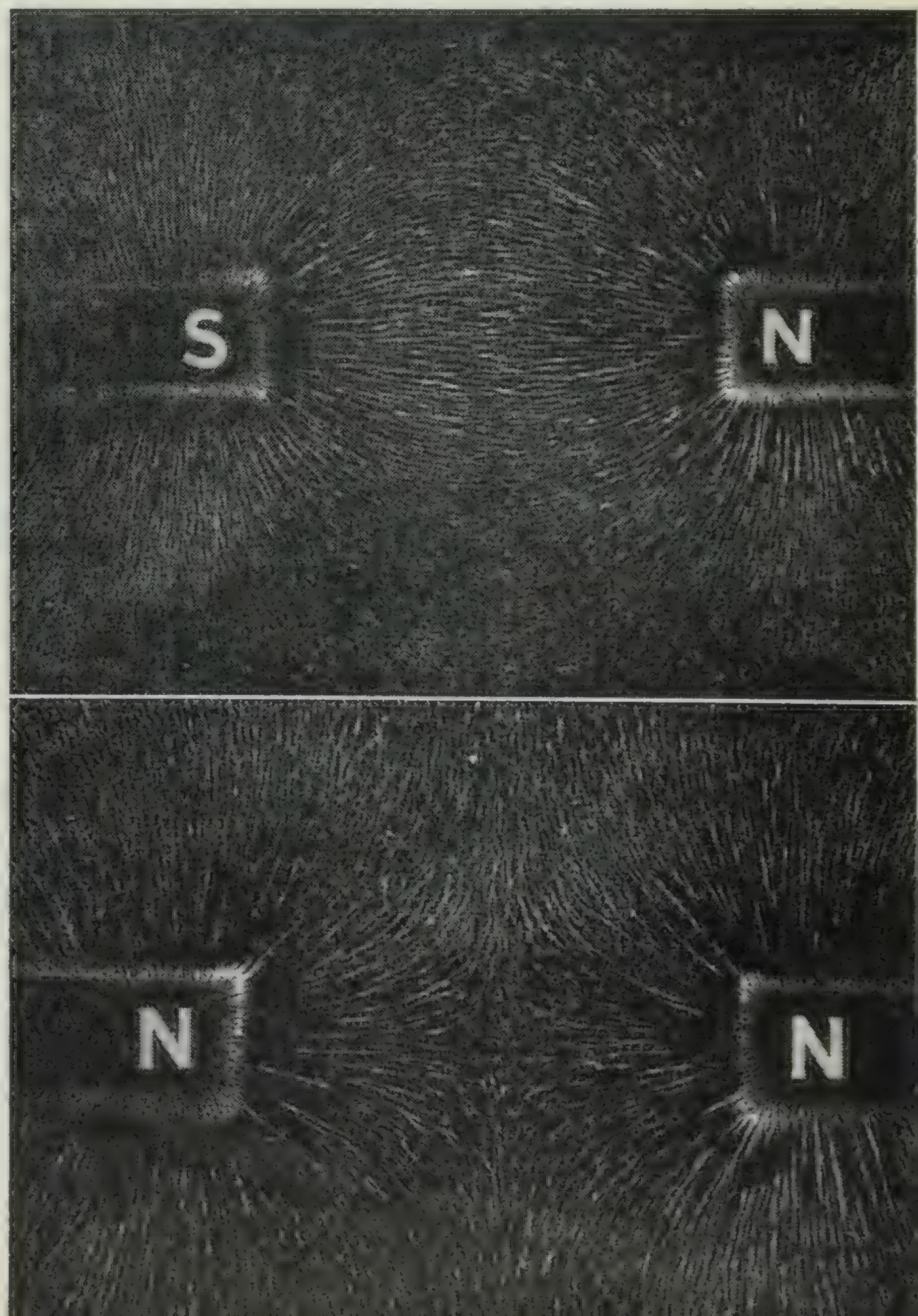
The curved lines into which the filings arranged themselves in your experiment mark the location of *lines of force* in the magnetic field of the magnet. These lines of force go through the air in curves from the N pole of a magnet to the S pole, then through the magnet back to the N pole.

The strength of the magnetic field becomes less as the distance from the magnet is increased. It is greatest at the poles.

SOMETHING TO DO

1. Make a drawing to represent the magnetic field about a bar magnet. Indicate the lines of force as you saw them in the experiment that you performed with the iron filings.
2. Obtain two bar magnets. Place them in line with unlike poles about two inches apart. Place a thin sheet of cardboard over them. Sprinkle iron filings on the cardboard. Tap the cardboard gently. Note the pattern formed by the iron filings between the poles. Make a

Top: Field of force about two unlike magnetic poles. Bottom: Field of force between two like poles. Be sure to do these experiments. Compare your results with those shown in these reproductions of photographs that were taken by a pupil to record his observations.



Scientists in the making. These pupils are learning about magnetism by performing experiments. Under the cardboard are two bar magnets with their ends about two inches apart. As the boy on the left shakes iron filings onto the cardboard, the boy on the right taps the cardboard gently. Try this and see what happens.

drawing to show the direction taken by the lines of force between unlike poles.

3. Repeat experiment 2, placing like poles (two N or two S) about two inches apart. Make a drawing to show the direction of the lines of force.

Try to account for the differences you observe in the arrangement of the lines of force in experiments 2 and 3. Remember that like magnetic poles repel and that unlike magnetic poles attract.

The earth as a magnet

Your experiments with magnets have shown that if they are suspended so that they are free to turn, they always come to rest in a north-and-south direction. Why is this? Could it be that there is a magnetic field around the earth and that this influences the compass needle or other suspended magnet?

SOMETHING TO DO

Strongly magnetize a darning needle. Fasten a fine thread around the needle and adjust it to the point where the needle is balanced horizontally.

Hold the needle about two inches above the middle of a bar magnet (see the illustration below).

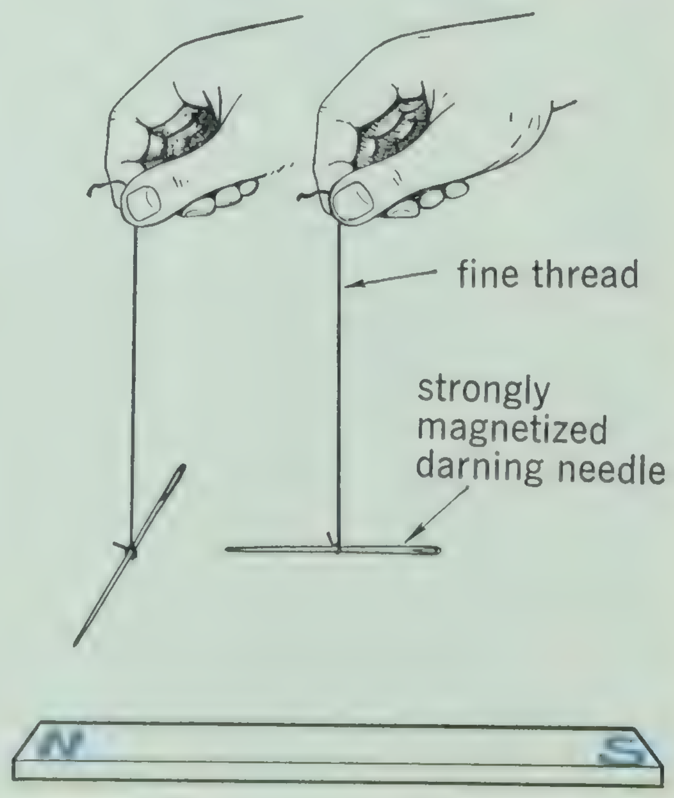
Slowly move the needle over one pole of the magnet. What do you observe?

Next move the needle over the other pole. What happens?

Now move the needle around the magnet in a horizontal plane. Note carefully the changes in the positions taken by the needle.

Make diagrams to show: (1) Positions taken by the magnetized needle as it is moved along over a magnet from one pole to the other. (2) Positions taken by the needle as it is moved around the magnet in a horizontal plane.

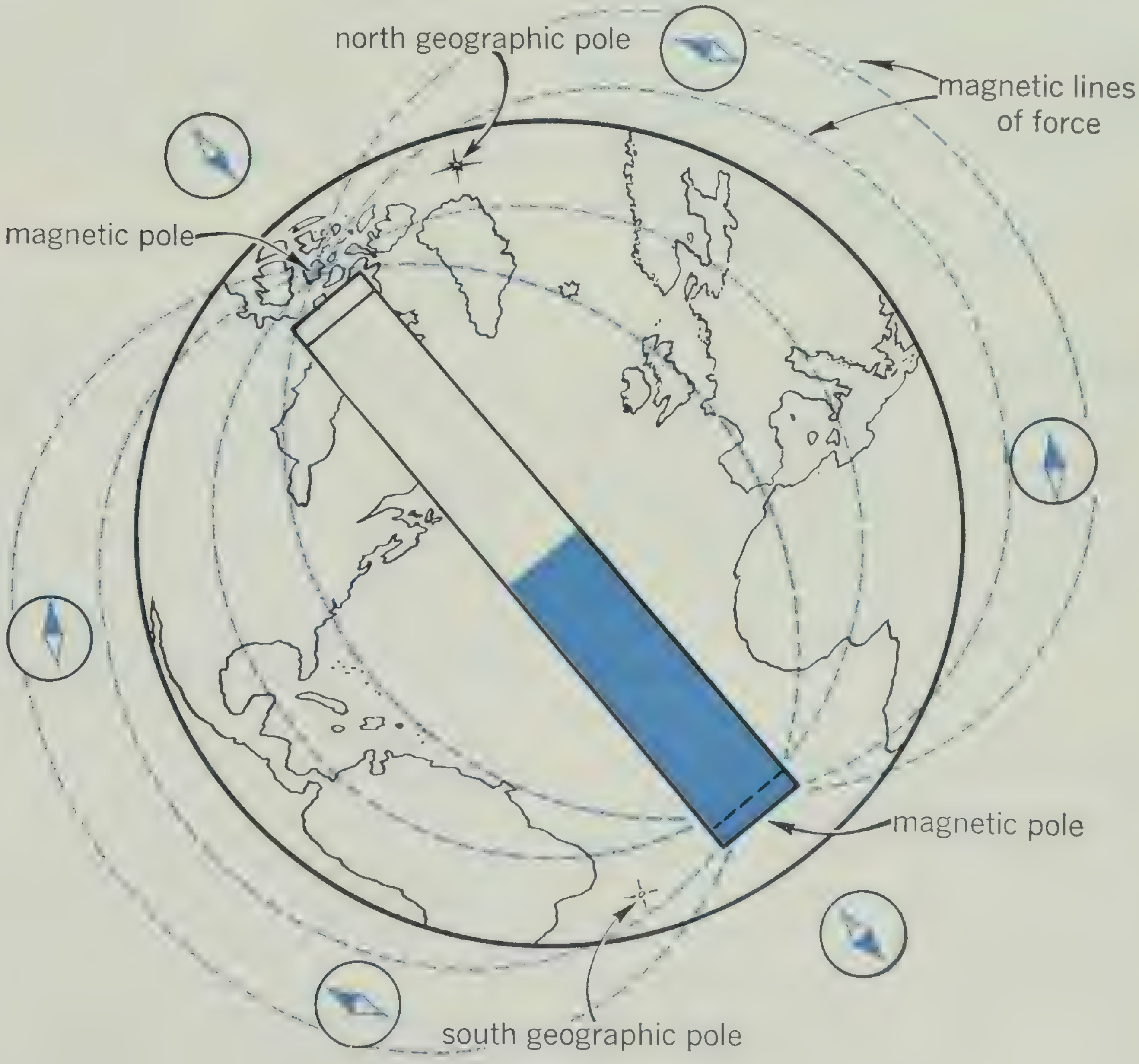
The suspended magnetized sewing needle that you used in your experiment served as a *dipping needle*. By using dipping needles at various



Dipping needle experiment. Explain how the dipping needle was an aid to explorers in locating the magnetic poles of the earth.

places on the earth, scientists have made some interesting observations. For example, they have found an area in the far north where the N or north-seeking pole of the dipping needle points directly downward toward the earth. Near the geographic south pole of the earth, an area has been found where the S or south-seeking pole of the dipping needle points straight downward. Between these two areas the dip is less.

Scientists have explained the interesting behavior of the compass needle and the dipping needle on the basis that the *earth itself behaves as a magnet*. Like any other magnet, the earth has two magnetic poles, one in the far north and another in the far south. Both of these have been discovered. Also, as with other magnets, there is a magnetic field surrounding the earth. Scientists believe that the lines of force of the earth's magnetic



The earth behaves as a magnet.

field influence the compass needle and the dipping needle and cause them to behave in the ways that you have observed.

In the drawing on page 145, you can see how the earth acts as a magnet. Find the north magnetic pole and the south magnetic pole. The N, or north-seeking, pole of a magnet is attracted toward the earth's north magnetic pole. It is not correct to call the N pole of a magnet a north pole; instead we should call it a *north-seeking* pole, or an N pole, as we have called it throughout this chapter. Because the N pole of a magnet is attracted toward the earth's north magnetic pole, these two poles cannot both be north magnetic poles. This is why we call the N pole of a magnet a north-seeking pole instead of a north pole.

What is the source of the earth's magnetism?

Scientists have not agreed upon an explanation of the earth's magnetism. Several theories have been suggested. One theory is that the *rotation of the earth* causes the earth's core to become magnetized. The earth's core, you will remember, consists chiefly of a solid sphere of iron which is about 2000 miles in diameter. The theory advanced in this instance is that the magnetized iron core is the source of the earth's magnetism.

A second theory is that the earth's magnetism is associated in some way with *sun spots* and other solar disturbances. It is suggested that the earth's magnetism comes from the sun. Magnetic storms on the earth occur at a time of great sunspot activity.

A third theory, called the *electron theory*, is based on the idea that there are electric currents within the earth that magnetize the earth's core making it into a huge electromagnet. The magnetic field about this great electromagnet comprises the earth's field of force.

It is more than likely that other theories to account for the fact that the earth behaves as a magnet will be advanced by scientists from time to time. Watch for announcements of any new discoveries relating to the earth's magnetism and report what you learn to your class.

The compass

Many a man has lost his life because he lost his compass. Do you know how to use a compass?

SOMETHING TO DO

1. Examine a compass at school or at home. Notice the compass needle. Test it to see if it is a magnet. Look closely to see if this magnetized needle is free to turn around in different directions.

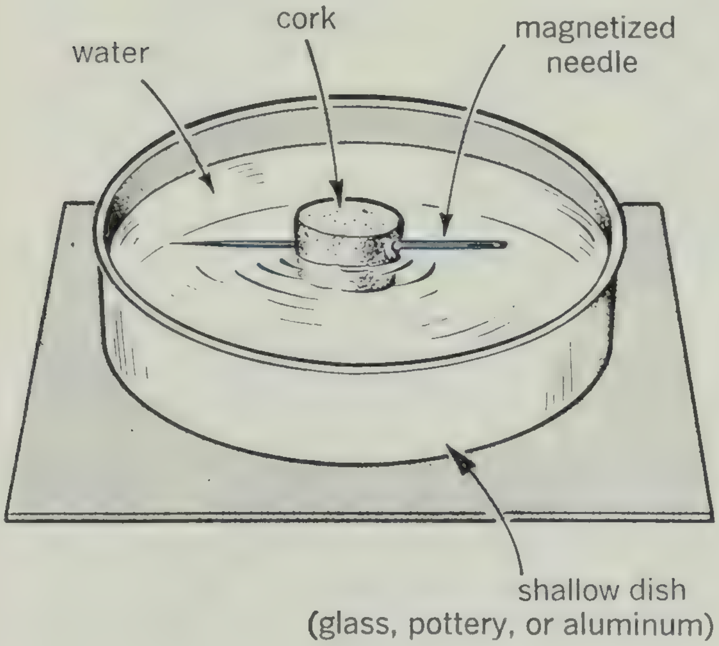
Do you find a card on which various directions are indicated? Of what material is the case of the compass composed? Why do you think this material is used? Find out how to use the compass to tell direction.

A compass consists of a *magnetized needle* suspended on a sharp point so that it is free to swing around, and

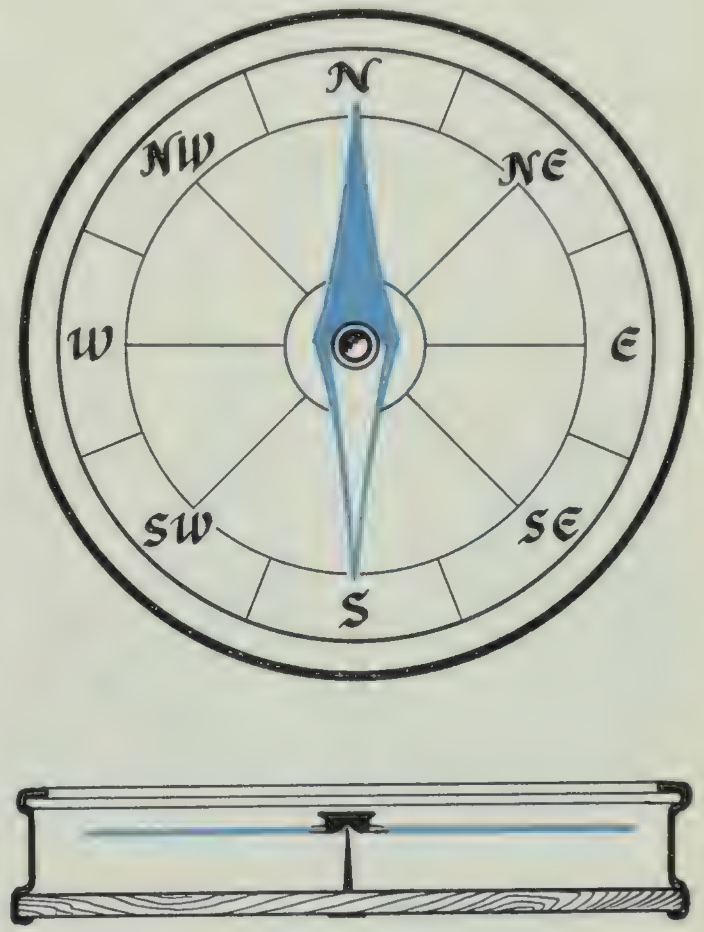
a *card* that shows the *directions* or *point of the compass.* The case of the compass is usually made either of brass or of a plastic substance. Such substances are not magnetic and, therefore, the compass case will not affect the compass needle.

Does a compass needle always point exactly north?

It was not until a few hundred years ago that it was demonstrated that suspended magnets are pulled around to a north-and-south position by the earth's magnetic force. In 1831, Sir James Ross, a British explorer, discovered the earth's magnetic pole in the north. It is on Prince of Wales Island, Canada, north-west of Hudson Bay. Find the location on a map. The south magnetic pole was found in 1909 by Professor David, who accompanied Sir Ernest Shackleton, a British explorer, on his expedition to Antarctica. The positions of the magnetic poles are slowly changing.



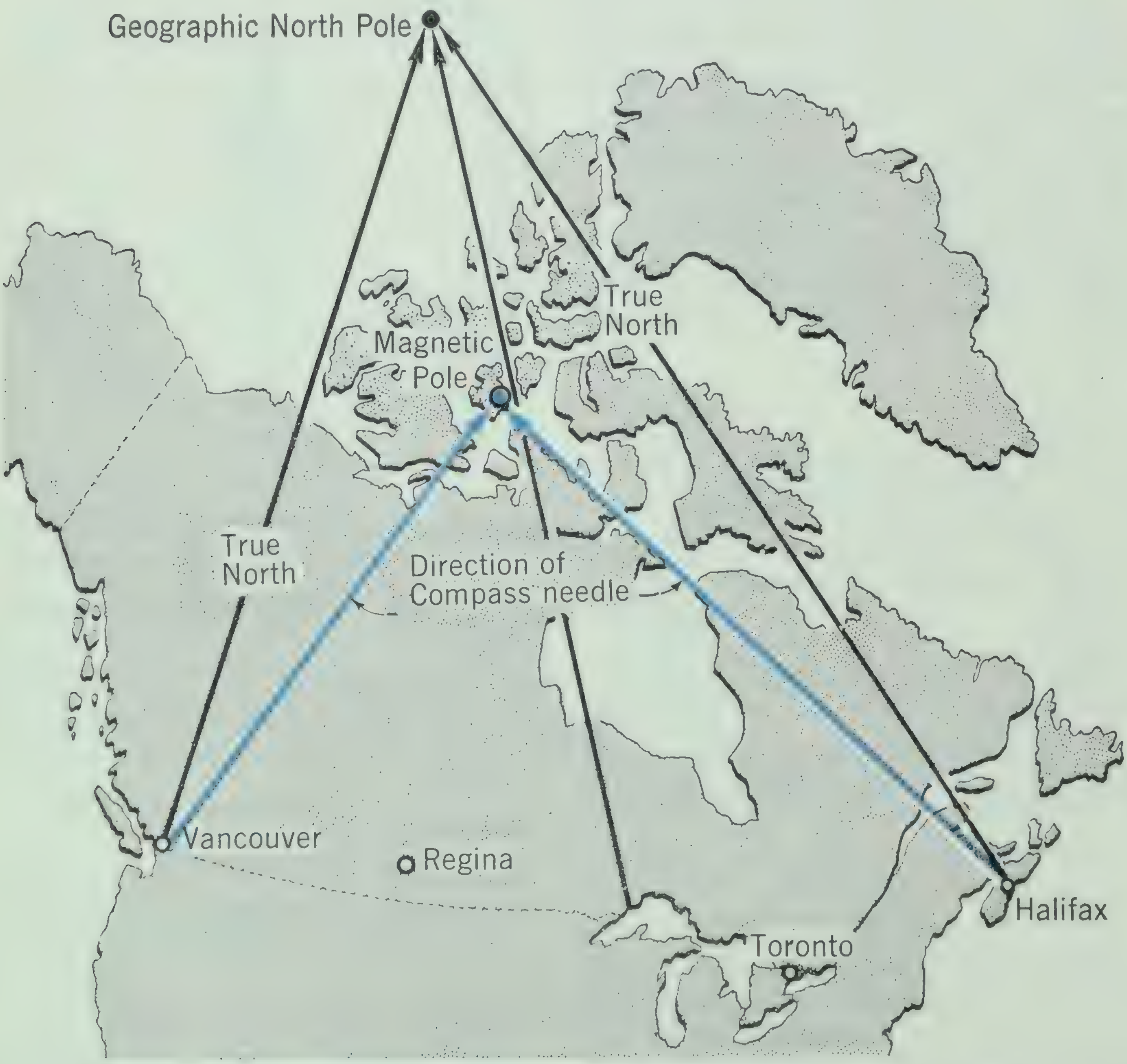
A simple home-made apparatus for finding direction. A darning needle is first magnetized and then pushed horizontally through the middle of a flat cork that floats on the water. When the cork becomes stationary, the magnetic needle points in a north-and-south direction. To be able to tell what direction north is, what will you need to know about the needle?



A simple compass. In this form the needle turns to the north, but the card under it must be turned to give the other directions correctly. The lower drawing shows a sectional view.

Do you know that *a compass needle does not always point exactly north and south?* When we say *north,* we mean toward the geographic north pole of the earth. The compass needle, however, points to the magnetic poles, each of which is over 1100 miles from the corresponding geographic poles. If you examine

the drawing on this page, you will quickly see why a compass needle does not point exactly north-and-south in most places. In some parts of the world, the compass needle points to the west of the geographic north-and-south line. In other parts, it points to the east of true north-and-south. In Western Canada, the compass needle points to the east of the true north-and-south direction. In Eastern Canada, it points to the west of true north-and-south. The angle that the compass needle makes with true north-and-south is called *magnetic declination.* Study the drawing



At Vancouver a compass needle points east of true north-and-south, while at Halifax it points west of true north-and-south. Why is this? Does the compass needle ever point straight north and south? If so, where? Nearby deposits of iron ore will affect the compass needle, causing it to point away from the true north. Does your compass needle point east of or west of true north-and-south in your locality?

on page 148. What is the approximate magnetic declination for the locality in which you reside? The chart at the right will help you to answer this question.

Magnetic declination is affected by magnetic storms, sun spots, northern lights, and other phenomena. It varies daily and with the seasons. Over the years, it changes by important amounts.

SOMETHING TO DO

Locate on a globe the north and south magnetic poles. What is the relation of each in relation to the corresponding geographic pole?

How to use a compass

The following exercise will help you to use a compass correctly.

SOMETHING TO DO

1. Hold the compass so that the needle swings freely. You must now turn the compass enough to allow for the variation between magnetic north and geographic or true north. In Western Canada, you must turn the compass in a *counter-clockwise* direction, that is to the *left,* as you face north, the number of degrees of magnetic declination for your locality. In Eastern Canada, you must turn the compass in a *clockwise* direction, that is to the *right,* as you face north (see the chart on this page). The points on the face of the compass will then indicate east, west, south, north-west, south-west, etc. Using a compass, find various other directions. Each time you use the compass, remember to turn it in the proper direction to allow for the correct number of degrees of magnetic declination for your locality. In Alberta the direction of true, or geographic, north is always to the *left* of the magnetic north shown on your compass. Similarly, the correct direction for east, south, and west is always to the left of the compass reading for these directions. If you live in or near Edmonton, for example, the true, or geographic, direction is 25 degrees to the left of the magnetic reading shown on your compass. Thus to find true, or geographic, north from Edmonton, locate the magnetic north on your compass. Hold the compass with the north-seeking pole of the magnetic needle directly over the N. Then turn the compass 25 degrees to the *left.* The new position of the N on the compass indicates true or geographic north.

2. If you do not live in or near Edmonton, try to find the correct magnetic declination for your locality.

Capital City	Degrees Compass Needle Points	
	East of true North-and-South	West of true North-and-South
Victoria	23	
Edmonton	25	
Regina	17	
Winnipeg	10	
Toronto		7
Quebec		20
Fredericton		22
Halifax		23
Charlottetown		25
St. John's		28

Uses of the compass

Christopher Columbus used a compass to help him find his way across the ocean in his search for a new land. So did other early explorers who travelled in sailing vessels on unknown seas for weeks on end. Today, all ships are equipped with compasses to aid the pilots in keeping on the right course (see the picture on page 127). Similarly, pilots and navigators of airplanes depend on the compass, usually of the *gyro* type, to guide them safely to their destinations, whether it be over land or sea.

Prospectors seeking new deposits of minerals in unsettled parts of the country always carry compasses with them to keep them from becoming lost. Wise sportsmen on hunting and fishing trips play safe by including a compass in their travelling kits. Indeed, for safe travel anywhere on land, sea, or in the air, a reliable compass is worth its weight in gold.

Everyday uses of magnets

Look around your home for ways in which magnets are being used. The receiver of a telephone contains a magnet. Perhaps your telephone pad and pencil are magnetized. What is the advantage of magnetism in these cases?

Sometimes the physician uses a magnet to extract bits of steel that are embedded in the eye of his patient. In certain industries, magnets are used to remove from mixtures harmful foreign materials such as nails. Magnets are essential parts of magnetos in automobiles. Magnetized tack hammers are used to advantage on occasion. These are but a few examples of the uses of magnets in our own environment.

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. How do scientists explain the fact that certain materials can be made into magnets while others cannot?
2. Make a drawing to illustrate the construction of a compass.
3. Will a compass accurately indicate directions if it is placed near a large iron object? Explain.
4. Does the needle of a compass in Ontario point in exactly the same direction as a compass needle in Saskatchewan? Why?
5. What reasons can you give for believing that the earth acts as a huge magnet?
6. At the geographic north pole, in what direction will the N pole of a compass needle point?
7. When an iron nail is held near one pole of a magnet, the nail becomes a temporary magnet. Explain what happens in this case.
8. How does a dipping needle help explorers find the earth's magnetic poles?

9. By means of a drawing, show the direction of the lines of force about a bar magnet.

10. An iron or steel post that has stood in an upright position for a long time is found to be magnetized. Explain how the post became a magnet.

11. If an explorer near the geographic north pole found his compass pointing south, would he be justified in concluding that his compass was at fault? Explain. Refer to the illustration on page 148 in answering this question.

12. Mention several important uses of magnets.

13. A hunter who is using a compass to find his way in the woods stands his gun off to one side before taking a reading of the compass. Why?

WHAT HAVE YOU LEARNED?

IMPORTANT SCIENCE IDEAS AND UNDERSTANDINGS

A

1. Travel by land, sea, and air has been made much safer by the use of the compass.
2. A magnet that is suspended so that it is free to turn about, comes to rest pointing in a north-and-south direction.
3. A magnet has the power to attract only a few substances, including iron, steel, nickel, and cobalt. These are called magnetic substances. Materials that are not attracted are called non-magnetic substances.
4. The force of a magnet can travel more easily through non-magnetic substances such as air, glass, and wood than through magnetic substances such as iron and steel.
5. The force of a magnet is strongest at its poles.
6. Like magnetic poles repel one another, and unlike magnetic poles attract.
7. The test for magnetism is repulsion.
8. One magnet can be used to make another magnet.
9. The space around a magnet through which the magnetic lines of force travel is known as the field of force.
10. Each molecule of a magnetic substance is believed to be a magnet.

11. The earth behaves as a huge magnet with one magnetic pole in the far north and the other in the far south.

12. The N pole of the compass needle points toward the earth's magnetic pole in the north, rather than to the geographic north pole.

(a) The foregoing sentences are all true statements of important science ideas and understandings. Read and discuss them carefully as a review of this chapter.

(b) The following sentences describe situations in which some of these ideas apply. To test your ability to apply ideas to new situations, match the sentences in A with situations in B to which they apply.

B

1. Fred Blake was having fun with a magnet. He moved the N pole of his magnet close to one end of a paper clip and observed that the paper clip was attracted. Next, he reversed his magnet and presented the S pole to the *same* end of the paper clip. Again the paper clip was attracted. Fred concluded that the paper clip was *not* a magnet.

2. Mark Waltman tested a soft iron rod and found it was not a magnet. He then held it in a north-and-south direction with one end pointing north and down toward the earth. While holding the iron rod in this position, he tapped it gently a number of times with a hammer. When he tested it again for magnetism, using a compass, he found that the rod was a magnet with an N pole at the end pointing north, and an S pole at the other end.

3. In Western Canada, a compass needle points to the east of true north-and-south, while in Eastern Canada it points to the west of true north-and-south.

4. A navigator of an airplane flying over the geographic north pole found that the N pole of the compass pointed toward the south.

5. Marilyn Patton was experimenting with a compass and a bar magnet. She found that the N pole of the compass needle took different positions as she moved the compass over and around the magnet.

IMPORTANT SCIENCE TERMS

A

magnetite	poles of magnet	compass
magnetic substance	permanent magnet	dipping needle

magnetism	field of force	earth's magnetic poles
alnico	lines of force	magnetic declination

To show that you understand and can use the science terms listed in A, match with the situations in B those terms which apply.

B

1. When Earl Crosby went to a store to buy a magnet, the clerk showed him one made of an alloy of three metals. It was very powerful, and so Earl decided to buy it.

2. In various places in Canada, explorers have found deposits of iron ore having the properties of a magnet.

3. Gary Fletcher moved his compass about a bar magnet. He noticed that the compass was affected by the magnetic force for a considerable distance in all directions from the magnet.

4. Betty MacDonald tested a large number of substances with a magnet and found that any object made of iron or steel was attracted by a magnet.

5. When she checked a Magnetic Declination Map, Ruth Kelly found that at Regina a compass needle points seventeen degrees east of true north-and-south, while at Toronto a compass points seven degrees west of true north-and-south.

SCIENTIFIC METHOD AND ATTITUDES

1. Janet Brown brought the pole of a magnet near to the pole of a second magnet which was suspended. The pole of the suspended magnet was attracted to the magnet in Janet's hand. She concluded, therefore, that the poles of magnets attract each other. You know that this conclusion was partially wrong. In what ways did Janet fail to use the scientific method in reaching her conclusion?

2. Suppose that you have always believed that a compass needle points to the true north. One day, a classmate suggests that you are mistaken and that this supposition is incorrect. In which of the following cases would you show evidence of a scientific way of looking at things:

(*a*) if you tell your classmate that he is wrong and refuse to listen to further discussion?

(*b*) if you think carefully about what your classmate has said, then consult one or more reliable science books to decide which of you is right?

(*c*) if you consult your science teacher, and together plan and carry out a number of tests to find the correct answer by experiment? Give a reason for your answer.

3. Many years ago, the reluctance of seamen to sail on a Friday reached such proportions that the British government decided to prove the fallacy of the superstition that a voyage begun on a Friday was ill-fated. The government had a new ship built; its keel was laid on Friday, it was launched on Friday, it was christened H.M.S. Friday, and was sent to sea on Friday. Neither ship nor crew was ever heard of again. Did this prove or disprove the superstition that Friday is unlucky? Explain your answer fully.

Genius hath electric power

Which earth can never tame,

Bright suns may scorch and
dark clouds lower,

It's flash is still the same.

—Lydia M. Child

CHAPTER 4

CHAPTER 4

ELECTRICITY AT REST AND IN MOTION

Electricity is so widely used today in our homes and elsewhere in our environment that we are apt to take it for granted. What is electricity? There are two kinds of electricity, namely, static electricity and current electricity; how can each kind be produced? A relationship exists between magnetism and electricity. What is this relationship and why is it of great importance? Energy can be changed from one form to another. How would you show, for example, that chemical energy can be changed into electrical energy? How can you distinguish between a dry cell and a battery?

ELECTRICITY is a mysterious and fascinating form of energy. It is only recently that man has learned about the nature of electricity, although the Greeks discovered how to produce static electricity over 2500 years ago. It was many centuries later, however, before scientists learned some of the secrets of this powerful, useful, but unseen force. There was a time when people shrank with fear at the sight of a brilliant flash of lightning across a stormy sky. Some people still do. Those of us who have studied science, however, know that lightning is a huge electric spark that jumps from cloud to cloud or from cloud to earth.

Although electricity has been regarded through the centuries as a mysterious and awe-inspiring force, man has succeeded in putting it to work in many ways. Today electricity carries messages with the speed of light, brings interesting happenings from distant places for our enjoyment, lights our streets, homes, and other buildings, operates labor-saving machines in homes and factories, and contributes in many additional ways to our health, happiness, and comfort. Indeed, so widespread are the uses of electricity in our environment that it would be correct to say that electricity has transformed our civilization.

What is the nature of electricity? Most of what we know about electricity has been discovered within the past 200 years, and much information has come to light only recently. These important discoveries about the nature

of electricity are the results of the work of many different scientists working in many countries throughout the world. You will learn something about these findings concerning the nature and behavior of electricity as you proceed with your study of this chapter.

ELECTRICITY AT REST

One cold winter morning, Janet Brown was combing her hair in preparation for school. She noticed that her hair seemed to be attracted to the comb. She also heard little snapping sounds and at times she thought she saw tiny sparks jumping between her hair and the comb. She wondered about these things and was curious to know the explanation of them. What caused the sparks?

That day in science class, Janet had an opportunity to tell the class about these experiences. Her classmates, together with her teacher, Mr. Kennedy, agreed that they should perform a number of experiments in an effort to find an answer to Janet's problem. You too should plan to try the experiments performed by Mr. Kennedy's class. They are described below.

SOMETHING TO DO

1. Rub a non-metal fountain pen, or a rubber or celluloid comb, with woollen or flannel cloth. Your sweater or coat sleeve may be used. Try to pick up pieces of paper or hair with the pen or the comb. Hold the electrified comb or pen close first to a water tap or a radiator, and then to your ear. Do you hear the snapping sound? What do you think caused the noise?

2. Rub a glass rod, or a piece of glass tubing, with a piece of silk. Try the tests suggested in experiment 1.

3. Comb your hair several times. Hold the comb near your hair. What happens when you do this?

4. Hold a piece of thin paper against a smooth wall. Rub it with a silk cloth or with your hand. Release your hold, and notice that the paper is held to the wall. If you do this in the dark, tiny electric sparks will be seen as you pull the piece of paper away from the wall. Explain what holds the paper to the wall. Try this with a long, inflated rubber balloon rubbed on the wall. Does it stick to the wall? Why?

5. Rub a cat's back in the dark. What do you hear and see?

6. Shuffle your feet on a heavy rug, then, with your finger, touch a tap or a radiator or someone's ear or nose. What happens?

A comb that has been rubbed with a woollen cloth is held near a water tap. What happens? Explain.

7. Support a small sheet of glass on two books. Tear small pieces of paper, or make tiny dolls or animals, and scatter them beneath the glass. Rub the glass with a piece of silk. What happens to the pieces of paper?

NOTE. – These experiments should be performed during a clear, cold spell in the winter, when the air will be dry. When there is much moisture in the air, it is difficult to electrify an object, because the electricity escapes.

In your experiments, you produced electricity by friction. Such electricity is called *static,* because it usually stands on a body, although it may jump from one body to another, often producing a spark and a snapping sound.

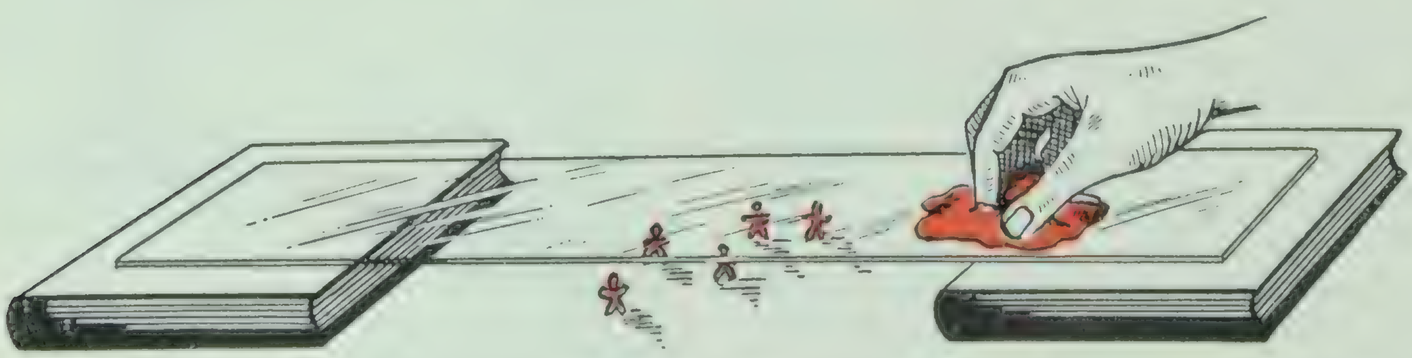
More than 2000 years ago, the Greeks discovered that, if a substance known as *amber* is rubbed, it will attract light objects, such as pieces of paper, hairs, or tiny chips of wood. The attraction in this case is not the result of magnetism. The substances referred to are not magnetic. The pieces of paper, etc., are attracted to the amber, a material resembling bakelite, because a charge of electricity is produced on it by rubbing it. The Greek word for amber is *electron,* from which our word electricity is derived. It is now known that a large number of substances other than amber can be electrified by means of friction or rubbing.

One of the most awe-inspiring examples of static electricity is lightning. You have seen the huge electric sparks that light the heavens when static electricity leaps from one cloud to another or from a cloud to an object on the earth.

What is electricity?

It is quite likely that you already know many things about electricity. For example, you probably know that electricity flows over wires and is used to provide us with light and heat for our homes and to ring the door-bell when we press a button. Have you ever wondered what electricity really is?

Scientists tell us that substances are composed of tiny particles called *molecules.* A molecule is so small that one cannot be seen with the aid of an ordinary microscope. However, in recent years, electron microscopes magnifying 200,000 times or more have made it possible for scientists



Try this experiment to see if you can make the paper dolls dance by rubbing the glass with a piece of silk.

to see some of the larger molecules and to photograph their structure. A thimbleful of air contains billions and billions of molecules. Each molecule is made up of still smaller bodies called *atoms.*

No one has ever seen an atom. Atoms are far too small to be seen, even with the aid of the most powerful microscope. Many years ago, scientists believed the atom to be the smallest particle into which any substance could be divided. Today, scientists do not think of the atom as a tiny speck of solid matter that cannot be divided. Instead, they liken it to a solar system with a central *nucleus* or "sun" around which particles called *electrons* revolve (see illustration below). The nucleus is composed of *protons* and *neutrons.*

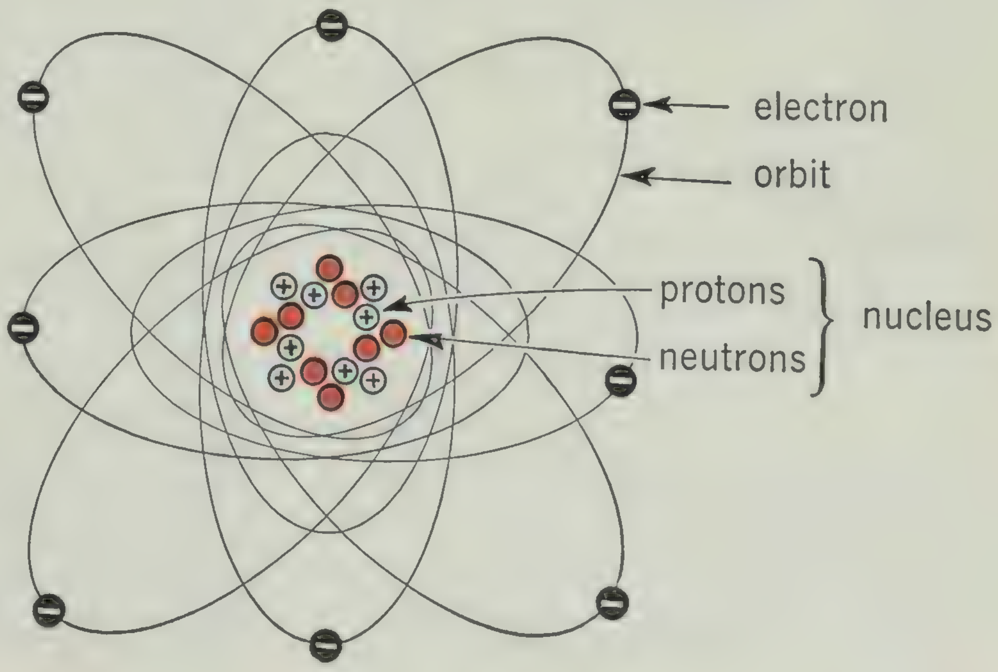
Scientists tell us that there are *two kinds of electric charges,* namely, *positive* and *negative.* A proton is a particle bearing one positive electric charge. An electron is a particle bearing one negative electric charge. A neutron is uncharged. Usually, the number of protons in an atom equals the number of electrons.

Atoms of the different elements, such as carbon, oxygen, and silver, differ in the number of protons, electrons, and neutrons that they contain. Hydrogen has the simplest atom; it contains only one electron and one proton. The helium atom has two electrons, lithium has three, and so on to uranium, which has ninety-two electrons in its atom.

Electrons can move freely through some substances, such as metal. When so moving, they produce a *current* of electricity. An electric current, therefore, is a *flow of electrons* along a conductor. Electrons can pass from one substance to another. You will learn more about this in the sections that follow.

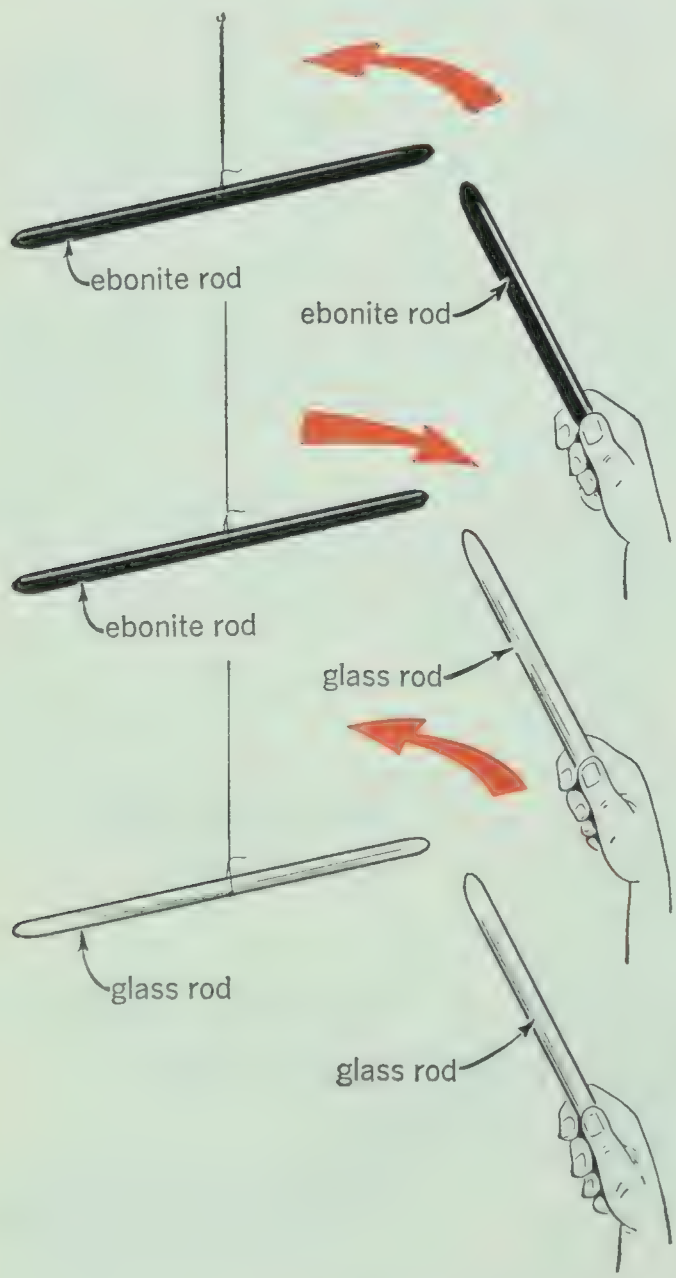
Examine the drawing below of an atom of oxygen. Locate and count the protons, neutrons, and electrons.

How a scientist pictures an atom of oxygen. The nucleus or central part contains eight protons and eight neutrons. Eight electrons revolve about the nucleus in their orbits. Atoms of the different elements differ in the numbers of protons, neutrons, and electrons that they contain. Hydrogen is the simplest atom, and uranium the most complex.



Kinds of electrical charges

You have already learned that electrical charges, known as static electricity, can be produced by friction. In performing the experiments outlined on page 157, you may recall that you were able to produce static electricity by rubbing a rubber or celluloid comb with a woollen cloth. You also found that you could produce an electrical charge on a glass rod by rubbing the rod with a silk cloth. This showed that electrical charges can be produced by using different combinations of materials. Are these charges all alike or are there different kinds?



Try these experiments several times.

SOMETHING TO DO

Problem. — Are there different kinds of electrical charges?

Apparatus and Material. — Two glass rods, two ebonite rods (or combs made of rubber or celluloid), woollen cloth, silk cloth, means of suspending a rod (see diagram at left).

Method and Observations. — (1) Charge an ebonite rod by rubbing it back and forth with a woollen cloth; then suspend it in a horizontal position so that it is free to turn. (2) Charge the other ebonite rod and bring its charged or rubbed end near the charged end of the suspended rod. What happens? (3) Hold one end of the glass rod firmly in your hand and rub the other end vigorously with the silk cloth to charge it. Bring the charged end of the glass rod near the charged end of the suspended ebonite rod. What do you observe? (4) Replace the suspended ebonite rod with a charged glass rod. Bring the charged end of this rod near the charged end of the second glass rod. What happens? (5) Bring the charged end of an ebonite rod close to the charged end of the suspended glass rod. What do you observe?

Conclusions. — (1) Were the electrical charges on the ebonite rod different from those on the glass rod? How do you know?

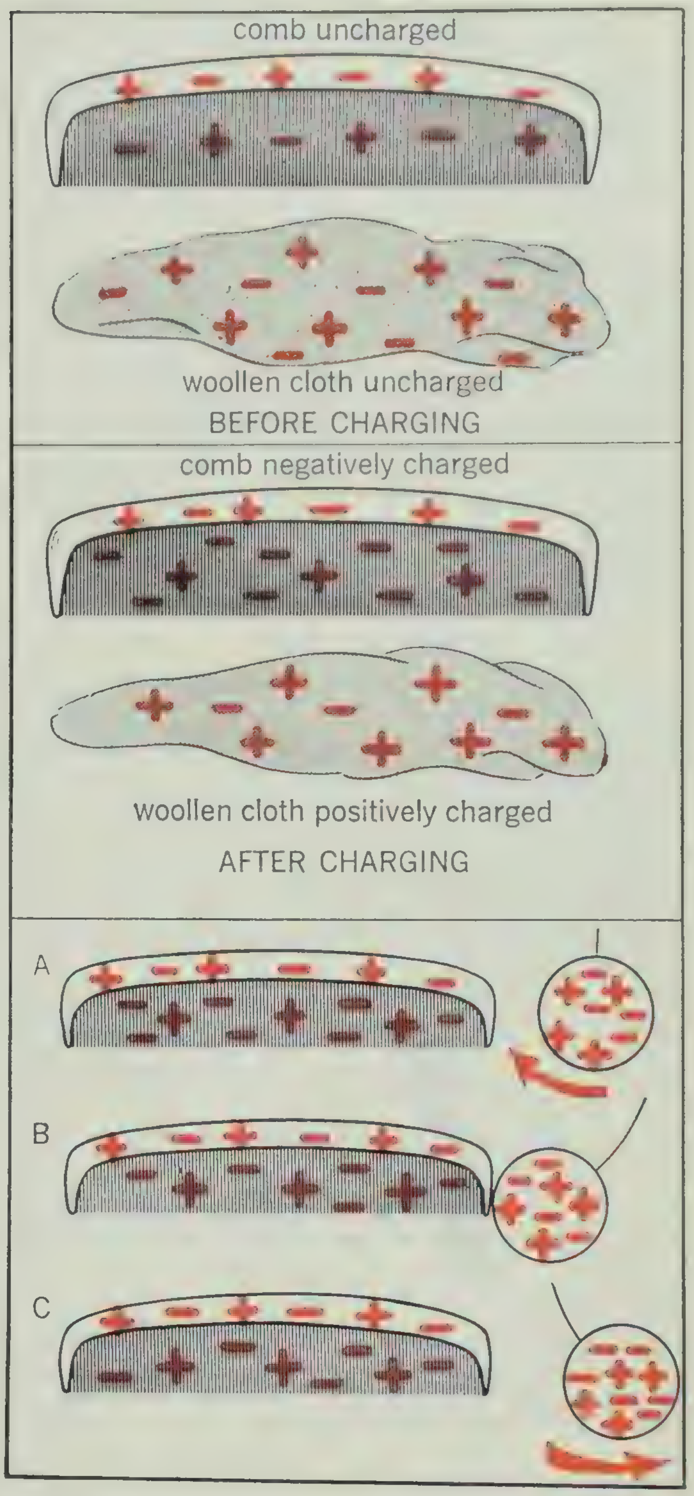
(2) How do like electrical charges behave toward each other?

(3) How do unlike electrical charges behave toward each other?

As a result of your experiments, it should be clear that there are two kinds of electrical charges. One kind may be produced by rubbing an ebonite rod or a rubber comb with a woollen cloth (or cat's fur). It is a *negative charge*. A negative charge is due to a *surplus of electrons*. Rubbing the ebonite rod with a woollen cloth adds electrons to the rod. Electrons move from the cloth to the ebonite rod.

A second kind of electrical charge is produced by rubbing a glass rod with silk. It is a *positive charge*. A positive charge is caused by a *shortage of electrons*. Evidently rubbing a glass rod with silk removes some of the electrons from the rod. It should be evident, therefore, that some materials can be given a positive charge and others a negative charge.

As you probably discovered in doing this experiment, negative electrical charges repel each other; positive electrical charges also repel each other. However, a negative charge and a positive charge attract each other. Therefore, *like electrical charges repel* and *unlike electrical charges attract*. This is known as the *law of electrical attraction and repulsion*.



A: Uncharged pith-ball attracted to negatively charged comb.
B: Some electrons move from comb to pith-ball and charge it negatively.
C: The comb and the pith-ball, now carrying like charges, repel each other.

How to detect and identify electrical charges

Scientists have invented instruments by means of which they can tell if an object bears an electrical charge; and also whether the charge is positive or negative. The instruments used for these purposes are called *electroscopes*. There are two common kinds of electroscopes, namely, the *pith-ball electroscope* and the *gold-leaf electroscope*. You will

find that you can make a pith-ball electroscope quite easily, and that it will be very useful in your study of static electricity.

SOMETHING TO DO

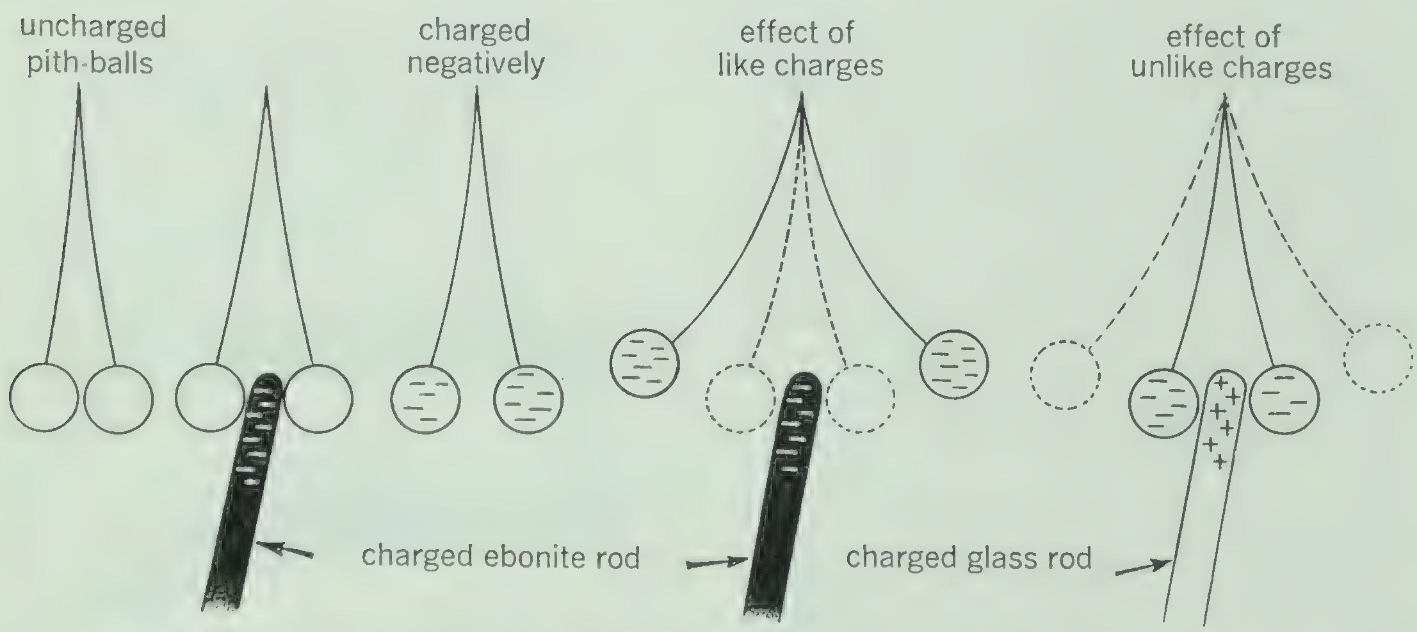
Make a simple electroscope by suspending two pith-balls by silk thread from a support and then putting a known electrical charge on them (see diagram below). Use this electroscope in the experiment that follows.

SOMETHING TO DO

Problem. — How can a pith-ball electroscope be charged negatively? Positively?

Method. — To determine how a pith-ball electroscope can be charged (*a*) negatively and (*b*) positively:

(1) Touch the pith-balls with an uncharged ebonite rod or with a rubber or celluloid comb. Does anything happen? (2) Rub the ebonite rod or comb with a woollen cloth to develop a negative charge on it. Touch the charged end to the pith-balls. What happens? (You may have to touch them several times before you obtain the desired result.) Now approach the rod toward the pith-balls. Are the pith-balls attracted or repelled? Keeping in mind that like electrical charges repel, what kind of charge is on the pith-balls? Where did they get this charge? (3) Repeat step 2 using a glass rod rubbed with silk to put a positive charge on the pith-balls.



A pith-ball electroscope. Check the results of your experiment with those shown here. Make another set of drawings to show what happens if you use a charged glass rod first, and later a charged ebonite rod.

NOTE. — Instead of using pith-balls for these experiments, puffed wheat, puffed rice, or very small balls of tissue paper may be used with good results. A coat of aluminum paint on the puffed wheat or puffed rice helps to assure satisfactory results.

Experiments with static electricity will give the best results if they are performed when the weather is *cold* and *dry*.

Repeat this experiment several times and check your observations on whether the pith-ball electroscope behaves in the same way each time.

Now explain how a pith-ball electroscope can be charged (*a*) negatively and (*b*) positively.

A simple way to distinguish electrical charges

SOMETHING TO DO

Problem. — To find how to detect and identify electrical charges.

Method. — (1) Suspend two pith-balls by means of silk threads as shown in diagram on page 162. (2) Charge the pith-balls *negatively* by touching them with a charged ebonite rod. (3) Approach the negatively-charged pith-balls slowly with a negatively charged rod and then with a positively charged rod. What happens? (4) Next charge the pith-balls *positively* by touching them with a charged glass rod. (5) Approach the positively-charged pith-balls with first a positively charged rod and then a negatively charged rod.

Observations. — What did you observe in steps 3 and 5?

Conclusion. — Account for what you saw.

Explain how a simple pith-ball electroscope can be used to detect and identify electrical charges.

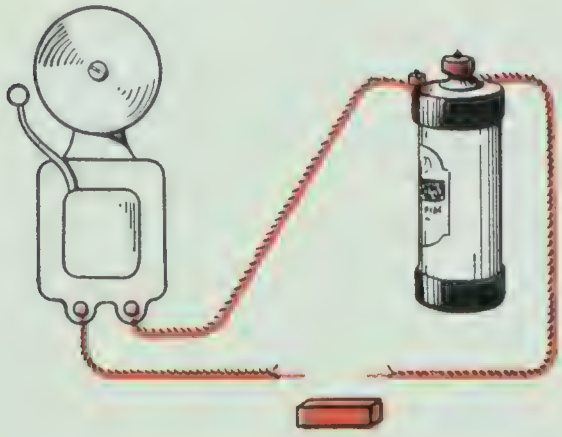
As you have learned, a charged ebonite rod has a negative charge, or a surplus of electrons. When a pith-ball is touched by the electrified end of an ebonite rod, some of these extra electrons move from the rod on to the pith-ball, giving it a negative charge, that is, a surplus of electrons. The negatively-charged pith-ball is repelled by the negatively-charged ebonite rod, but attracted by the positively-charged glass rod. This is what you would expect to happen in keeping with the law of electrical attraction and repulsion — like electrical charges repel; unlike electrical charges attract.

A charged glass rod has a shortage of electrons which leaves the rod with a surplus of protons (positive electricity), or a positive charge. An uncharged pith-ball contains an equal number of electrons and protons. However, when an uncharged pith-ball is touched with a glass rod carrying a positive charge, some electrons are attracted from the pith-ball to the glass rod. This leaves the pith-ball with a shortage of electrons, or a surplus of protons; the pith-ball is then positively charged. As you will have discovered, the charged glass rod repelled the positively charged pith-ball; and the negatively charged ebonite rod attracted it. State the law that again is illustrated by this part of your experiment.

Electric conductors and insulators

Substances in which electrons can move with ease are known as *conductors.* Materials in which electrons move only with great difficulty are called *insulators.*

From the experience that you have had with electricity in your home, what kinds of materials would you say are good conductors? What materials



An experiment to discover which substance will conduct an electric current and which will not. Assemble the apparatus as shown. Test, in turn, pieces of chalk, wood, tin, rubber, cloth, iron, and silver by touching them with the bare ends of the copper wire. If the bell rings what is indicated? If the bell does not ring what is indicated? A substance along which an electric current will flow freely is called a *conductor*; a substance that will not carry a current is a *non-conductor* or *insulator*. Which substances have you found to be conductors and which insulators?

are poor conductors, or insulators? It is not difficult to distinguish between conductors and insulators.

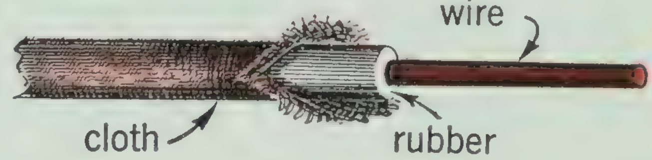
SOMETHING TO DO

1. *Problem.*—How can you tell whether a substance is a conductor or an insulator?

Method. — To determine whether a substance is a conductor or an insulator: (1) Place a negative charge on a suspended pith-ball by touching it with a charged ebonite rod or a rubber or celluloid comb. (2) Approach the charged pith-ball with the charged ebonite rod. Is the pith-ball repelled? (3) Next hold a steel knife or other steel object against the pith-ball for a second or two. (4) Again approach the pith-ball with a charged ebonite rod. Is the pith-ball repelled as in step 2? If the pith-ball has lost all or most of its electric charge, where did the charge go? Is steel a conductor of electricity? (5) Repeat steps 1, 2, 3, 4 several times. (6) Replace the steel knife, in turn, with other such materials as wood, glass, rubber, copper, porcelain, aluminum, and silver, and repeat steps 1, 2, 3, and 4.

Which materials removed or conducted the electric charge away from the pith-ball? Would these substances be known as conductors or insulators?

In which cases did the electrical charge on the pith-ball not move from the pith-ball to the material being tested? What name would be given to these materials?



Wire with two layers of insulation. Wire with this kind of insulation is used to bring electricity to our lamps. Insulation keeps the electric current in the wire.

The results of your experiment should prove that metals such as iron, copper, aluminum, and silver are good conductors of electricity; also that non-metals such as wood, glass, rubber, and porcelain are poor conductors, or insulators. In other words, electrons move readily through conductors, but with great difficulty through insulators.

2. Give examples to illustrate how rubber, porcelain, and glass are used as electrical insulators in your home.

NOTE. — Another experiment to find which materials are good conductors of electricity and which are insulators is described at the top left of this page.

A spectacular display of lightning. Lightning is a huge electric spark that jumps from cloud to cloud or from cloud to earth. If you are out-of-doors during an electric storm, what precautions should you take to avoid being struck by lightning? (Dominion Meteorological Service photo)

What is lightning?

More than 200 years ago a famous scientist, Benjamin Franklin, established by experiment the fact that lightning and electricity are one and the same thing. In other words, lightning is simply a huge electric spark.

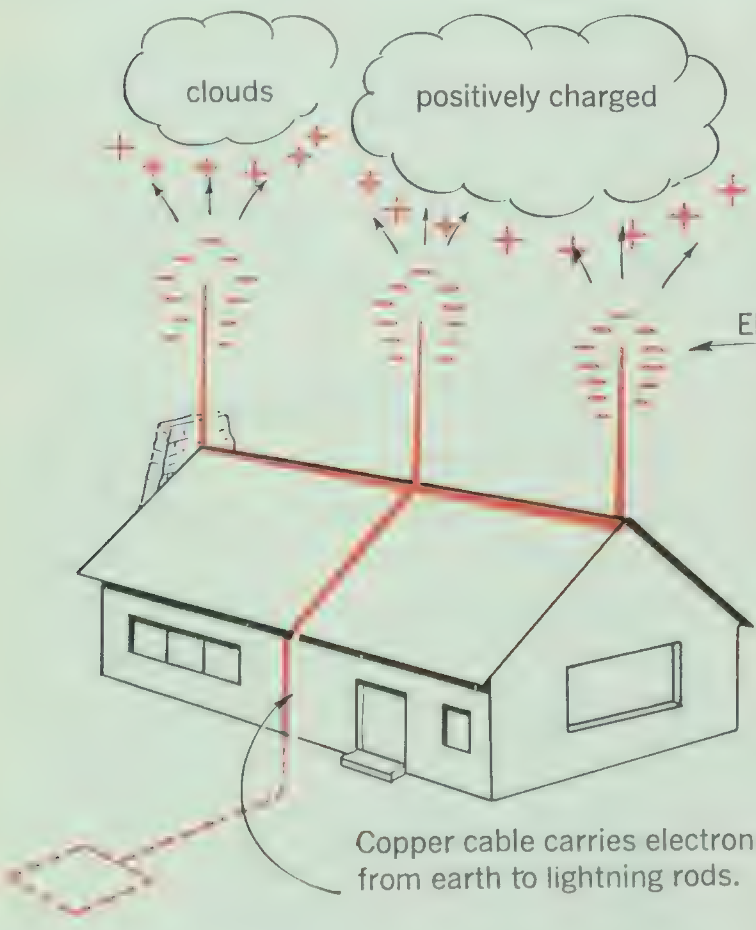
There are several theories as to how the electrical charges that cause the lightning are built up in the clouds; however, it is known that such charges do exist at times and that they do lead to thunderstorms. It is understandable that if a strong negative charge is produced on one cloud and a positive charge is produced on another cloud, a rush of electrons from the first cloud to the second may occur. This would produce a flash of lightning. Or again, a gigantic electric spark or lightning might be caused by a discharge of electrons between a cloud and an object on earth bearing an opposite charge. In general *lightning is a discharge of electricity built up in clouds.*

During electrical storms, conditions develop which cause electrical discharges to take place between two parts of the same cloud, between different clouds, or between clouds and the earth. These discharges, or flashes of lightning, intensely heat the air particles through which they pass, and cause collisions among them. The collisions produce a loud noise called *thunder*. As light travels about 186,000 miles per second, while sound travels

only about 1100 feet per second, you will understand why you usually do not hear the clap of thunder until several seconds after you have seen the flash of lightning.

During a thunderstorm it is interesting to estimate how far away a brilliant flash of lightning occurred. To do this, estimate the number of seconds between the flash of lightning and the time you hear the clap of thunder; then calculate the distance sound would travel in that time. Suppose, for example, that the elapsed time was 5 seconds; the sound would travel 5 x 1100 feet, or 5500 feet, in that time. This would indicate that the streak of lightning was about a mile away.

Sometimes during an electrical storm, buildings, trees, and even people are struck by lightning. Clouds carrying a strong positive charge will cause a tall object on the earth to be highly charged negatively. Then suddenly there is a discharge between the clouds and the object, and the high building or tree is "struck by lightning." Buildings may be protected from such dangers by the use of lightning rods, which gradually receive electrical charges during the storm and discharge them into the earth, thereby preventing a sudden flash of lightning. Sometimes electrons travel from the moist earth to the points of the lightning rods, from where they are discharged. The discharge of



Properly installed lightning rods protect homes and other buildings from the danger of being struck by lightning.

moist earth

the electrons neutralizes the positive charges that have developed on the clouds overhead and thus protects the building.

If you are out-of-doors during a thunderstorm, do not stand under a tree; trees are often hit by lightning.

Static electricity may cause accidents

There is evidence of the presence of static electricity all about us. Electrical charges sometimes are built up by friction to the point where an electric spark results. Such sparks are dangerous and may be the cause of serious accidents. For example, people who use dry cleaning fluids must be careful when rubbing the clothes not to cause an electric spark which, in turn, may ignite the cleaning fluid and cause an explosion. You should *never use gasoline to remove spots from your clothing.* There have been many accidents in which people were burned to death because they were using volatile and readily combustible dry-cleaning fluids indoors.

Operators of gasoline trucks usually drag a chain from the rear of the truck to carry away electrical charges that are sometimes produced by the friction of the tires on the road. This prevents a charge being built up to the point where an electric spark might result, which, in turn, could ignite the gasoline fumes.

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. Name two kinds of electrical charges and tell how you would proceed to produce each kind.
2. Describe an experiment to discover the law of electrical attraction and repulsion. State the law.
3. (*a*) How would you make a pith-ball electroscope?
   (*b*) How would you use this electroscope to tell whether an object is (1) uncharged, (2) negatively charged, (3) positively charged?
4. A negatively-charged body has a surplus of electrons; a positively-charged body has a shortage of electrons. By means of drawings illustrate these two conditions with regard to electrical charges.
5. (*a*) Define (1) electrical conductor and (2) electrical insulator. Give two examples of each.
   (*b*) If you were asked whether a certain plastic dish was a conductor or an insulator, how would you proceed to find the answer experimentally?
6. (*a*) Explain, in your own words, how lightning is formed.
   (*b*) How do lightning rods protect buildings from being struck by lightning?

MAGNETISM AND ELECTRICITY

Are magnetism and electricity related?

You have already found by experiment that when you bring a pole of a bar magnet near a compass needle or a suspended magnetized needle the compass needle is affected. You will recall that the magnetic needle either turned toward the bar magnet or away from it, depending on whether you were presenting an unlike magnetic pole or a like magnetic pole.

Do you know if a wire carrying an electric current will cause a compass needle to swing to one side? If it will, then a wire along which an electric current flows behaves as a magnet. In order to find these things out for yourself, you should perform the following experiments.

SOMETHING TO DO

Problem. — Is there a magnetic field about a wire carrying an electric current?

Apparatus and Material. — A dry cell; 2 to 3 feet of insulated copper wire; a compass.

Method and Observations. — Remove the insulation from both ends of the wire. Attach a bare end of the wire to one binding post of the dry cell. Stretch the wire so that it lies *over* the compass and in line with the needle. Now make the following tests:

(1) *Close the circuit* through the wire by touching the free end of the wire to the other binding post *for a second or two.* What happens to the compass needle? To which side does it swing?

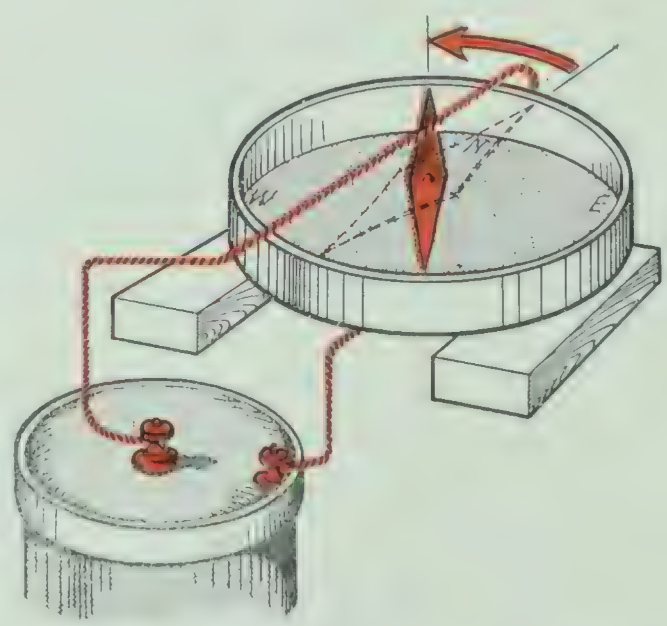
(2) *Break the circuit* by taking the wire away from the binding post. What effect has this on the compass?

(3) Repeat step 1 and step 2 several times.

(4) Place the wire *under* the compass and repeat steps 1 and 2. Does the needle of the compass swing to the opposite side this time?

(5) Next send the electric current through the wire over the needle in the *reverse direction* by switching the wires to the opposite binding posts. Does the needle swing around? Does it swing in the same direction as in test 1 or in the opposite direction? Close and open the circuit several times and observe the compass in each case. Is the needle affected in the same way each time?

(6) Again place the wire *under* the compass and complete the circuit so as to cause the current to travel through the wire in the same direction as in step 5. What difference do you observe in the



Be sure to perform this experiment. How can you tell if an electric current is flowing through a wire?

movement of the compass needle this time?

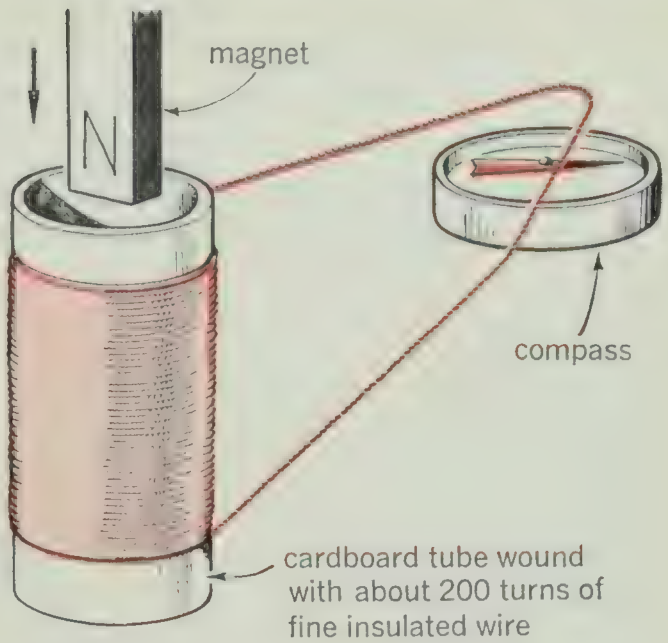
Conclusion. — Does an electric current flowing through the wire over a compass needle cause it to swing to one side?

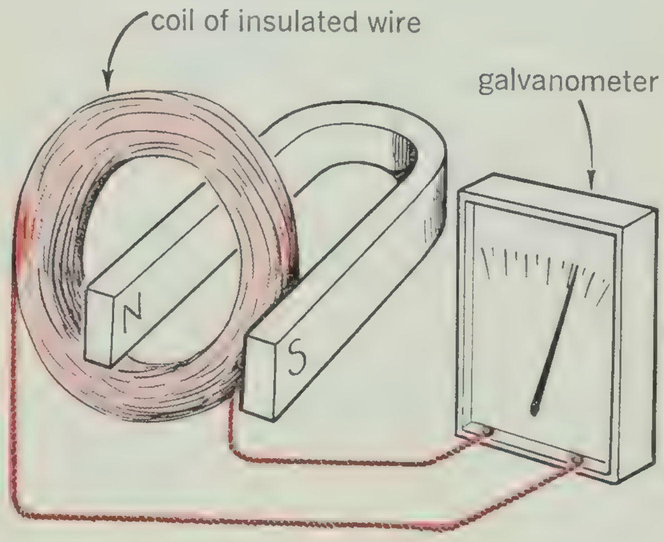
Does an electric current flowing in a wire under a compass needle cause the needle to swing to the opposite side?

Does reversing the direction of the current reverse the side to which the needle swings?

Finally, what is the answer to the question or problem that we have been investigating?

Your experiments should show that *there is a magnetic field surrounding a wire carrying an electric current.* From this it would appear that *magnetism and electricity* are related.





Two ways of doing the experiments described in parts 1 and 2 of the Something To Do section, below.

Can magnetism cause a flow of electricity?

In the preceding experiment you learned that magnetism and electricity are related. You will find further evidence of this very important scientific fact as your study of this chapter proceeds. Keeping in mind the scientific method of solving problems, you will want to perform experiments whenever you can to help you arrive at the correct answer to important questions and problems.

SOMETHING TO DO

What happens when a bar magnet is rapidly pushed into, and pulled out of, a coil of wire? To find the answer:

1. Make a coil consisting of many turns of insulated (covered) copper wire. Remove enough of the insulation from both ends of the wire so that the bare ends can be joined by twisting them together (see top diagram, above). Pass the wire over a compass needle, as shown.

NOTE. — If a galvanometer, such as the one shown in the second diagram, above, is available, connect the bare ends of the wire to the poles of the galvanometer (instead of joining them together).

2. Rapidly thrust the N pole of a strong bar magnet into the coil of wire and observe any movement of the compass needle (or galvanometer needle).

3. Hold the magnet in the coil for a few seconds without moving it. Observe the magnetic needle.

4. Quickly pull the magnet out of the coil. What happens to the needle?

5. Repeat steps 2, 3, and 4 several times.

6. Using the S pole of the magnet, repeat steps 2, 3, and 4 several times.

7. Next try to hold the bar magnet steady and thrust the coil over one pole. Is the compass needle affected? Quickly pull the coil away from the magnet. What happens?

8. Repeat step 7, but use the other pole of the magnet. What do you observe?

On the basis of your observations, what do you conclude?

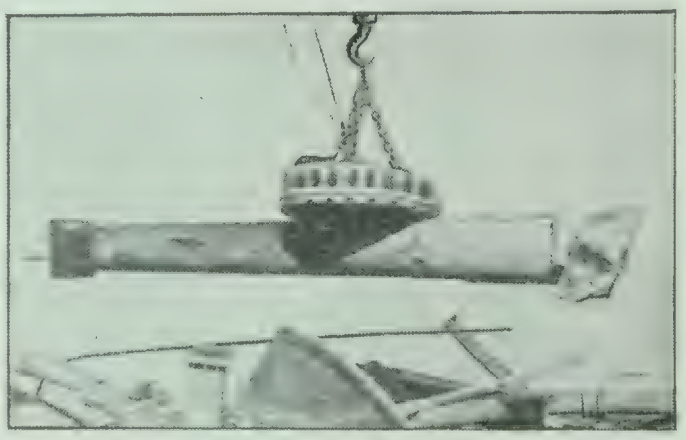
Remember that your conclusion should be an answer to the question asked at the beginning of the experiment.

You will have observed that when the pole of a magnet was thrust quickly into the coil of wire (a conductor) the compass needle turned to one side and that when the magnet was pulled rapidly out of the coil, the first swing of the needle was to the opposite side; also, that when the bar magnet was kept stationary and the coil of wire thrust over one of its poles the compass needle moved sideways and that when the coil was withdrawn quickly, the first swing of the needle was to the opposite side.

These tests show that *when a conductor cuts through the lines of force of a magnetic field an electric current is caused to flow in the conductor.* In other words, *magnetism can be used to produce electricity.* This was a most important scientific discovery for it led to the invention of the dynamo which is now so widely used in the large-scale production of electricity for commercial and industrial purposes. You will learn more about the use of the dynamo in the production of electric energy in your study of the next chapter of this book.

Using an electric current to make a magnet

As you have learned, scientists have been able to show that there is a magnetic field of force about a wire carrying an electric current. Scientists have made use of this fact in making magnets in which the magnetism is produced by an electric current. Such magnets are called *electromagnets.*

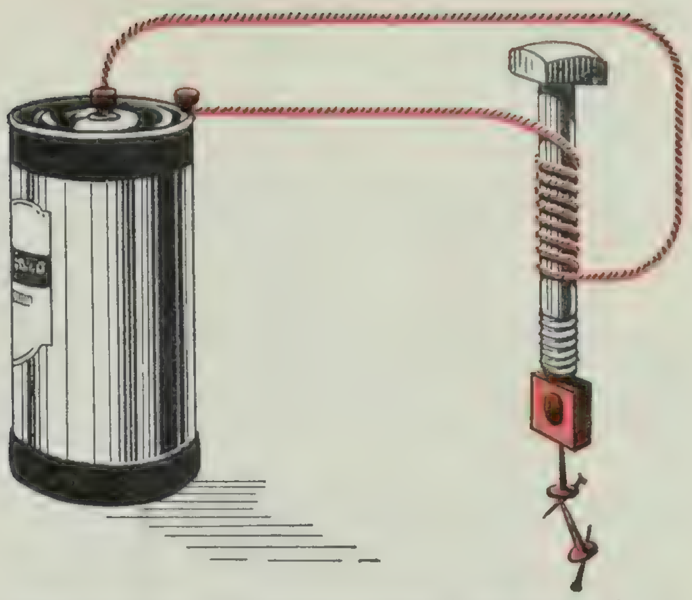


A large electromagnet lifting an iron column weighing eight tons.

SOMETHING TO DO

Problem. — How can an electromagnet be made and operated?

Apparatus and Material. — A soft iron bolt about 4 to 6 inches long; 10 feet or more of insulated copper wire (No. 20 or 24 double cotton-covered, or fine bell wire); one or two dry cells; several small



A home-made electromagnet in action. A push button or a switch could be included, to open and close the circuit.

pieces of soft iron, such as small bolts and nuts, short lengths of stove pipe wire, tacks, etc.

Method. – Test the bolt for magnetism by discovering whether it will pick up small pieces of iron. Neatly wind the insulated wire around the bolt as many times as the length of your wire permits. To a binding post of the dry cell, attach one end of the wire. Close the circuit by holding the other end of the wire so that it touches the other binding post of the cell. Now test the bolt for magnetism by discovering whether it will pick up pieces of iron. Open the circuit by disconnecting one wire, and closely observe what happens.

Caution: *Do not leave the cells connected for more than a few seconds at a time.* If you do, the cells will soon be damaged.

Observation. – Was your bolt a magnet to begin with? When an electric current was sent through the turns of insulated wire, did the bolt become a magnet? For how long did the bolt retain its magnetism when the circuit was broken?

Experiment several times to be sure that you can answer each of these questions correctly.

Conclusion. – State briefly how an electromagnet can be made. How can it be operated so that it will pick up a load and release it exactly when desired?

An electromagnet is usually made by passing an electric current through an insulated wire that is wrapped around a soft iron core. As you no doubt learned from your experiment, an electromagnet loses its magnetism immediately the circuit is broken. This fact is utilized in the operation of instruments such as the electric bell and the electric telegraph, in which electromagnets are used. Some of the practical uses of the electromagnet will be considered in the sections that follow.

Upon what does the strength of an electromagnet depend?

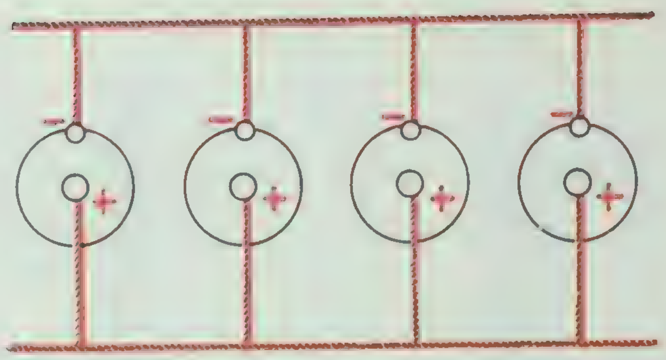
You may find the answer to this question by experimenting with a home-made electromagnet such as the one shown above.

SOMETHING TO DO

1. Connect up your apparatus as shown in the diagram on page 172. (Use electric light bulb from a flash light, dry cells, No. 20 insulated copper wire, soft iron bolt).

2. Vary the number of turns of wire in the electromagnet – use 10 turns, 20 turns, 40 turns. In each case test to find how many tacks the electromagnet will pick up, using one dry cell for each trial. What do you conclude?

3. Vary the strength of the current by using a different number of dry cells connected in *parallel* (see drawing at right). Be sure to use the same number of turns of wire in the electromagnet for each trial. Find out how many tacks the electromagnet will pick up in each case. Does increasing the current cause the strength of the electromagnet to be increased?



Cells connected in parallel — negative to negative and positive to positive.

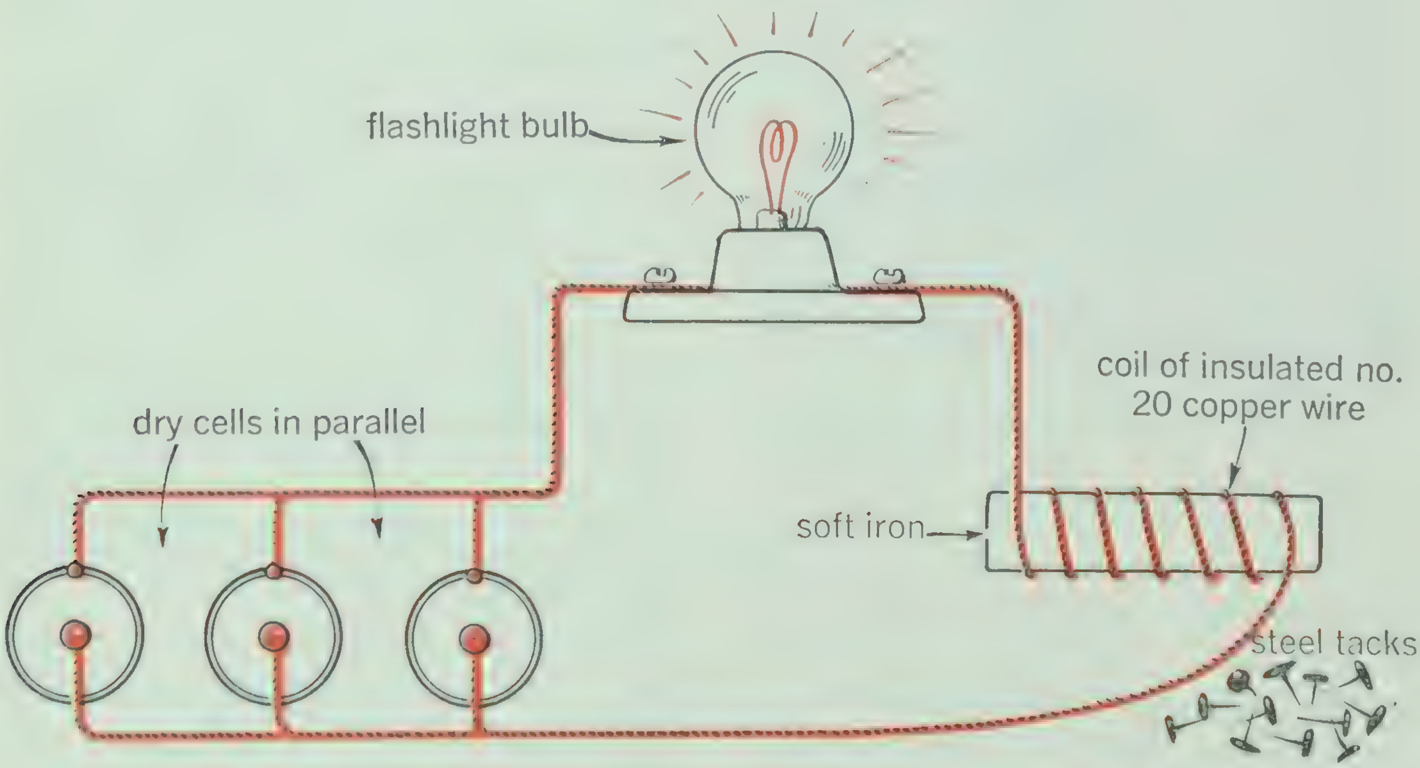
Your experiment should show that the *strength of an electromagnet depends upon the number of coils of wire and the strength of the current.* If the current remains the same, the more turns of wire there are, the stronger the magnet becomes. Also, the greater the current strength, the more powerful the electromagnet.

Why is it necessary to use insulated wire for the coil of an electromagnet?

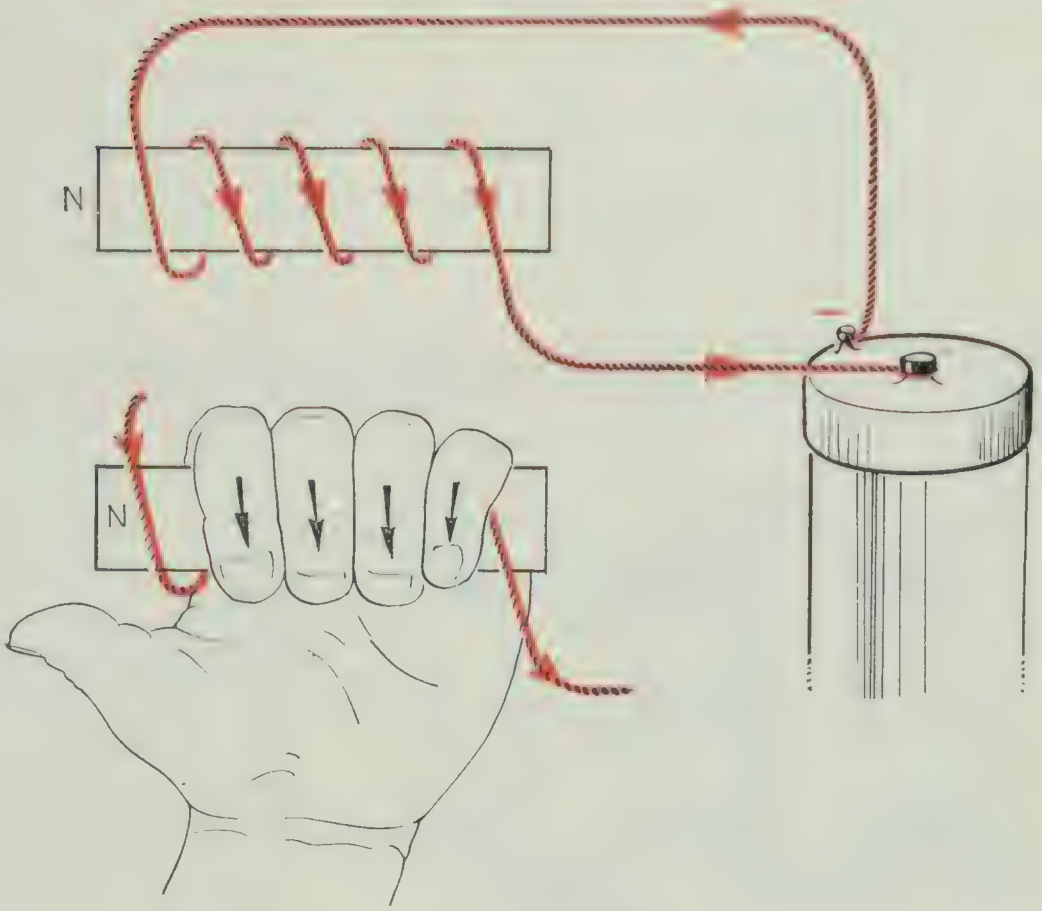
Polarity of an electromagnet

There are several ways in which you can determine which end of an electromagnet is the N pole and which is the S pole.

1. With the aid of a compass, find which end of the electromagnet repels the N pole of the compass. With this information, and by applying your knowledge of the law of magnetic attraction and repulsion, you can



Experiment to find what the strength of an electromagnet depends upon. Does increasing the number of coils of wire increase the lifting power of the magnet? Does increasing the electric current by using more dry cells connected in parallel result in a stronger electromagnet?



Left-hand rule. If we assume that electricity flows from the negative pole to the positive pole, we can determine the polarity of an electromagnet in the following manner. Grasp the coil with the left hand so that the fingers circle the electromagnet in the direction in which the current is flowing. The thumb will then point toward the N pole of the magnet.

readily determine the polarity of the electromagnet.

2. A second way of determining which end of an electromagnet is the N pole and which end is the S pole is to make use of the *left-hand rule.*

It is often important to know in what direction an electric current (flow of electrons)is moving through an electric circuit. Scientists are now generally agreed that the electron flow is from the negative pole of a cell to the positive pole. Therefore, when a dry cell is connected up in a circuit, the electric current leaves the cell by the negative pole (outside post), and travels through the electric circuit back to the positive pole (centre post) of the cell.

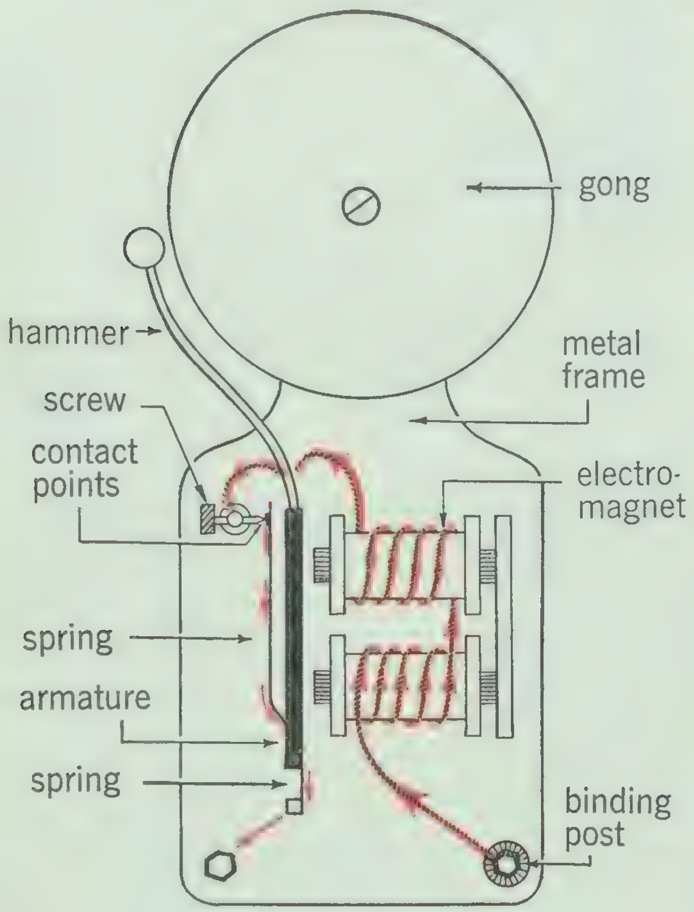
To determine the polarity of an electromagnet by means of the *left-hand rule,* proceed as follows:

Grasp the electromagnet with your left hand so that your fingers point in the direction of the electron flow through the coil; your thumb will then point to the N pole of the magnet. (See illustration above).

You should practise using the left-hand rule to find the polarity of electromagnets. Check your results by the compass method of determining polarity.

How does an electric bell operate?

A good example of how the electromagnet is used to advantage in various instruments is to be found in the electric bell. You should examine an electric bell to find its main parts. Also you should experiment with it to discover how it works. Take special note of the part played by the electromagnet in the operation of the bell.



← An electric door-bell at the instant the push-button at the door is pressed. Trace the path of the current through the bell. The current travels from the bottom of the spring to the left-hand binding post through the metal base of the bell. What happens to the electromagnet when the circuit is closed? What effect has this on the armature. Why? When the armature is attracted toward the electromagnet, the circuit is broken at the contact points. Draw the bell in this position. Why does the armature move back to its original position? Explain fully why the bell rings.

Look for the part that resembles the electromagnet that you made. The electromagnet of the bell consists of two spools, connected by a strip of iron, or yoke. Connect the bell to a dry cell, and notice which part of the bell moves when it is ringing. If possible, adjust the *contact point* by turning the screw (see the illustration on this page). What effect has this action on the ringing of the bell? Does it make the bell cease ringing if you turn the contact screw too far? Why? Change your connections, and discover whether it makes any difference which way the electric current flows through the bell. Can you trace the path which the electric current must take in flowing through the bell? (Watch for *insulation* at binding posts, contact screw, and other parts.) Notice whether loose connections, for example at the *binding posts*, cause any difference in the ringing of the bell. Can you find what causes the *hammer* (see the diagram) to move back and forth to ring the bell? What part does the electromagnet play in the action of the bell? Of what use is the spring?

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. Give evidence to show that there is a relationship between magnetism and electricity.
2. What are the essential parts of an electromagnet?
3. How is the strength of an electromagnet affected by (1) increasing the number of turns of wire, (2) increasing the strength of the current?
4. Why must an electromagnet be wound with insulated rather than with bare copper wire?
5. Make a labelled diagram of an electric bell. Trace the course of the current through the bell.

6. Explain what happens when the electric circuit through the bell is (1) closed, (2) opened.

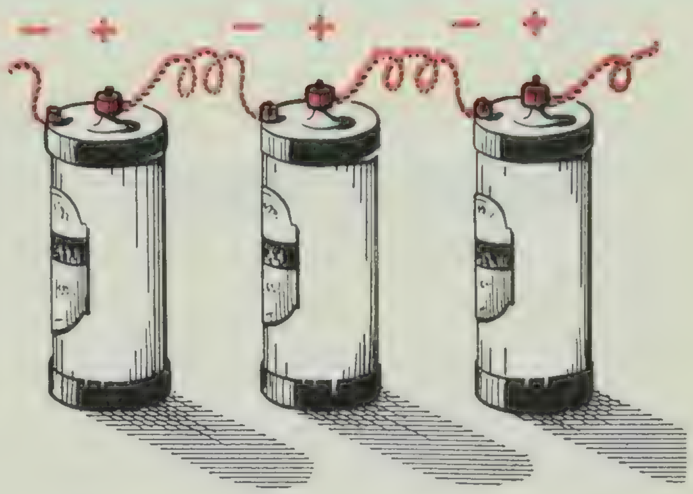
7. What part does the electromagnet play in the action of the bell?

PRACTICAL USES OF ELECTROMAGNETS—TRANSMITTING MESSAGES

The electromagnet has many practical uses. One of them is in the electric bell, which we have already studied. We shall now discuss the part played by the electromagnet in transmitting messages by telegraph and telephone.

The electric telegraph

Two hundred years ago, man had no way of transmitting messages rapidly over great distances. He depended upon runners or horse-back riders to carry important news from one place to another. No matter how urgent the message, several days were required to have a message delivered a few hundred miles away. Today, this can be accomplished in a matter of seconds. What has led to this great improvement in communication? First of all, scientists had to learn how to produce electricity and then how to use it. They had to invent instruments such as the telegraph, telephone, radio, and television and develop ways of using electricity in their operation. As a result of the work of these scientists we now have several ways of sending messages at the very great speed of 186,000 miles per second.



A battery of dry cells connected in *series*, for example, from the + pole of one cell to the − pole of another. This is the usual way to connect cells for ringing door-bells, etc.

One of the first ways of sending messages by means of electricity was by the *electric telegraph*. Perhaps you have heard the clicking of the electric telegraph in the office at a railway station as messages are received from, or sent to, other stations along the railway line. In many towns and villages the electric telegraph is also used in sending and receiving telegrams.

The electric telegraph was invented by Samuel Morse, after many years of strenuous effort. The first long-distance message was sent from Washington to Baltimore on May 24, 1844. It read, "What hath God wrought?"

Morse also gave us the code of signals used in sending telegrams.

A simple telegraph set consists of two instruments: a *key* to send the message, and a *sounder* to receive it. It is not difficult to make a telegraph set. The following suggestions will help you. Perhaps you can invent instruments of your own design and send messages with them.

MORSE CODE

·—	—···	·· ·	—··	·	·—·	——·	····	··	—·—·
A	B	C	D	E	F	G	H	I	J
—·—	——	——	—·	· ·	·····	··—·	· ··	···	—
K	L	M	N	O	P	Q	R	S	T
··—	···—	·——	·—··	·· ··	··· ·	·——·	··—··		
U	V	W	X	Y	Z	1	2		
···—·	····—	———	······	——··	—····	—··—	· ·		
3	4	5	6	7	8	9	0		

The Morse Code is used in railway and commercial telegraphy in Canada and the United States.

SOMETHING TO DO

1. *Problem.* — To make a home-made telegraph set.

Apparatus and Material. — (1) For the *sounder:* a piece of board about 6″ × 8″ × ⅝″ for the back; a piece of board about 3½″ × 8″ × ⅝″ for the base; two strips of wood for cleats or supports; a soft iron bolt about 5½″ long, with two nuts to fit; a screw eye (like that used to hook a screen door) just large enough to allow the smaller bolt to pass easily through it; a small nail for a stop; a small screw hook; a rubber band. (2) For the *key:* a board for the base; a piece of metal spring; screws or tacks for contact point and binding post. (3) *Additional materials:* 10 feet or more of fine insulated copper wire (No. 20 to 24), and one or two dry cells.

Method. — To construct the sounder: Fasten the wooden cleats or supports to the base as shown on page 177. Nail the base and the back together. Wind the larger bolt with as many turns of insulated wire as your supply of wire permits. You have now made an electromagnet. At one side of the base, and just far enough out from the back to allow a nut to be turned on the larger bolt, bore a ½-inch hole. Insert the threaded end of the larger bolt into the hole, and fasten it securely, placing the nuts as

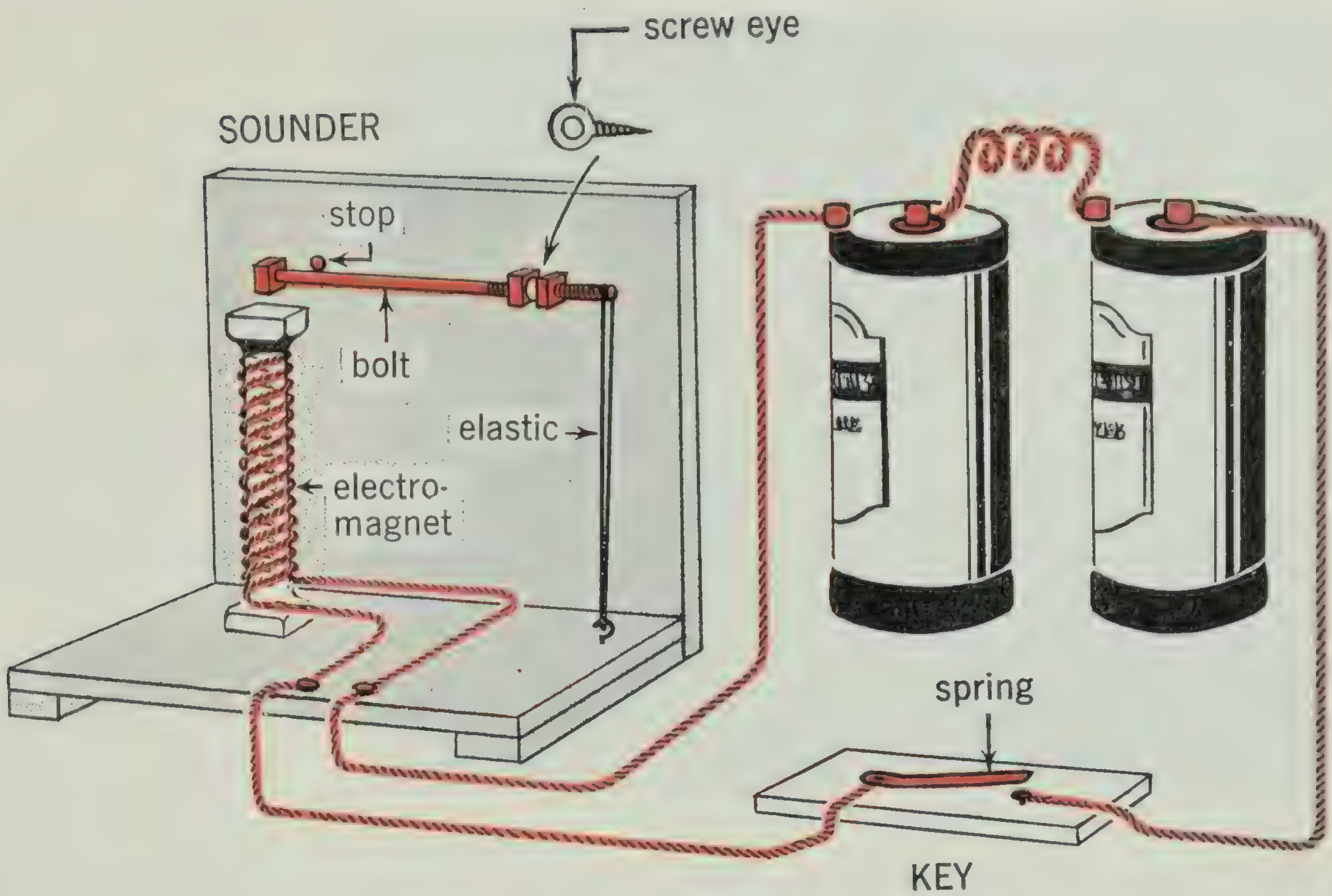


Diagram of a home-made telegraph set. Be sure to make one and use it to learn how messages can be sent by telegraph.

illustrated, that is, one above and one below the baseboard.

Next, study the diagram carefully to learn how the second or smaller bolt is arranged. The screw eye should be placed so that the smaller bolt will lie in a horizontal position when its head is resting on the head of the larger bolt, and so that, when the two nuts are adjusted, about ¾ of an inch of the threaded end of the bolt projects through the second nut. One side of the head of the smaller bolt should be filed flat, unless a square-headed bolt is used. Then fasten the smaller bolt loosely in place by nuts, as shown in the drawing above, and adjust the nuts until the head of the smaller bolt rests on the head of the larger one.

Now place the stop in such a position that, when the head of the smaller bolt is held up against the stop, it will be $\frac{1}{16}$ of an inch from the head of the larger bolt. Fasten the elastic band in place, arranging it so that it holds the smaller bolt firmly but not too tightly against the stop. The sounder is now complete and ready for use.

Construct the key as illustrated on this page. Connect the key, sounder, and dry cells as shown in the diagram. Your set is now ready to test. Press the key to close the circuit. The smaller bolt should be pulled down with a sharp click. Release the pressure on the key. The smaller bolt should be pulled up with another sharp click.

Do not be disappointed if your set does not operate satisfactorily right away. It may need adjusting. Perhaps the elastic is too tight or too loose. Perhaps the stop is too high, so that the

A telegraph operator is sending a message in code by operating a telegraph key. Notice that the key switch is open. A telegraph sounder is shown in the background. Note the electromagnet. (National Film Board photo)

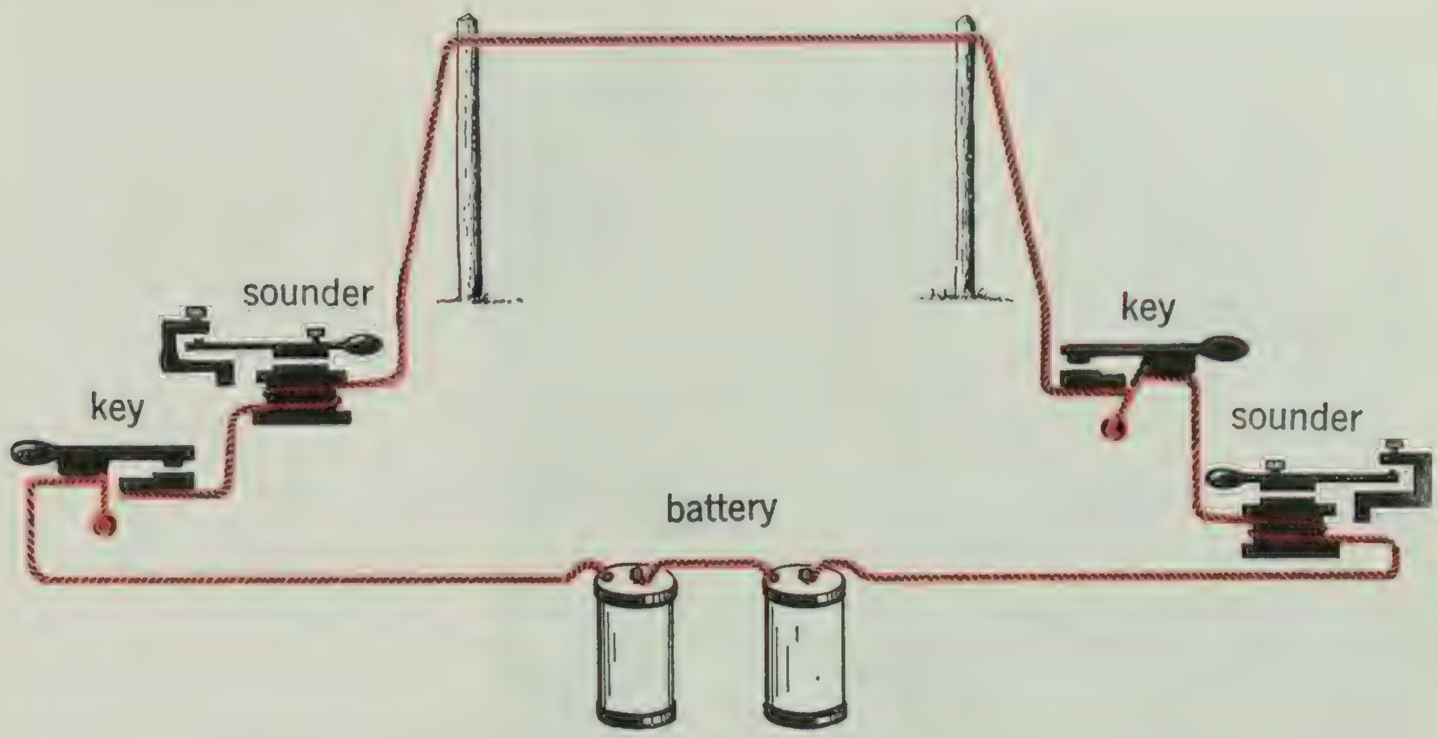
smaller bolt is held too far away from the electromagnet. If you experiment a little with these adjustments, you should soon have the proper arrangement.

Observation. — What happens to the smaller bolt when you close the circuit by pressing on the key? Why does this occur? What happens to the smaller bolt when you break the circuit? Did you hear a click as the smaller bolt was pulled down against the top of the electromagnet? Did you hear a click as the elastic pulled the smaller bolt up against the stop? Is there a difference between the sound of the *down* click and that of the *up* click? When someone else is operating the key, can you tell by the sound of the click whether the smaller bolt has moved up or down? Learn to recognize the two sounds.

How to send a message. — Close and open the circuit (press and release your key) several times in quick succession. A short time between the down click and the up click is termed a *dot.* Close the circuit, and pause before opening it. This allows a little longer time between the down and the up clicks, and the result is a *dash.* Combinations of dots and dashes are used to represent the letters of the alphabet. Try to spell out your name on the sounder, using the Morse Code (see page 176). You may practise the code with a pencil or a penknife, tapping on two surfaces that produce different sounds. Practise signalling messages to a classmate.

2. Visit the local telegraph or railroad agent. Ask him to show you how standard telegraph instruments are constructed and operated. Listen to him sending and receiving messages. He will be using the Morse Code.

3. Perhaps you and a classmate can make two sets of instruments and send messages from one end of the schoolroom to the other, or farther. When you are sending messages to each other, there must be no break in the circuit at the station receiving a message. Keep



A two-station telegraph circuit. Note that the switch of the key at the right is closed and that the switch of the key at the left is open. What will happen in the sounders when the operator presses the key at the left so as to close the circuit? Explain. What will happen when he releases the key and thereby breaks the circuit? Why?

the circuit closed at the receiving station by continuously pressing on the key, or add a switch to the key to permit this to be done more conveniently.

The telephone — a means of communication

It is difficult for us to realize that as recently as eighty years ago, the telephone was unheard of as a means of communication. Today, in Canada alone, over two and one-half million telephones are in use, and these carry about four billion conversations each year.

The story of the invention and amazing advancement in the improvement of the telephone as a means of communication resulted from man's ever-increasing ability to master the forces of nature and to use them to his advantage.

The invention of the telephone

The inventor of the telephone was Alexander Graham Bell. Born in Edinburgh, Scotland, Bell came to Canada in 1870 to join his parents at Brantford, Ontario. The following year he went to Boston where he gave lectures to teachers of deaf children in the use of visible speech. Later he opened a school in Boston for the correction of stammering and other speech defects. It was these interests that set him thinking along the lines that led to the invention of the telephone.

During the summer holiday at Brantford, in 1874, Alexander Graham Bell outlined to his father his now historic idea: "If I could make a current of electricity vary in intensity precisely as the air varies in density

Alexander Graham Bell, left, and his assistant, Mr. Watson, on the day in 1876 when Bell's invention of the telephone proved successful. Upon hearing Dr. Bell's words coming from the receiver, Mr. Watson rushed from the adjoining room to say: "Dr. Bell, I heard every word you said—distinctly." (Bell Telephone Company photo)

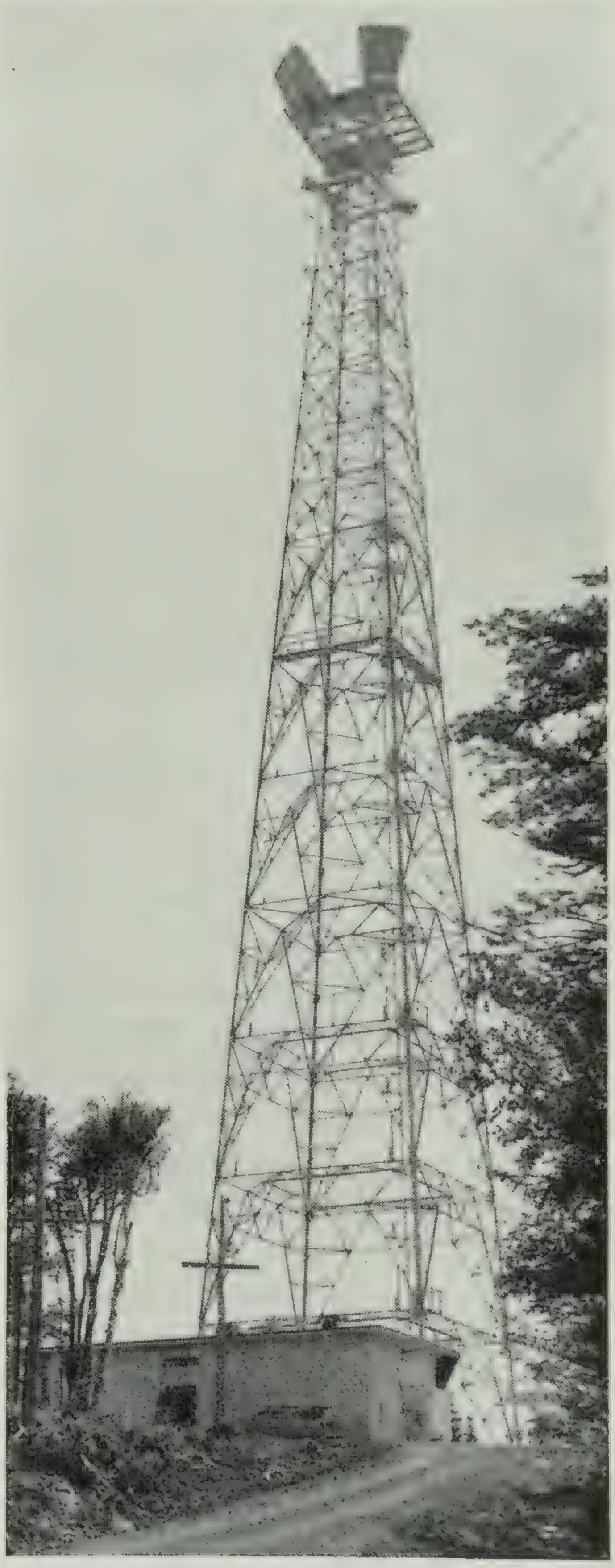
during the production of a sound, I should be able to transmit speech telegraphically." Bell worked on his idea with great concentration. He built an apparatus that would transmit meaningless sounds. After endless hours of work and thought he succeeded in improving his device, which consisted of two similar instruments employing the same principle as the modern telephone receiver. On March 10, 1876, while experimenting with his apparatus, Bell called to his assistant, "Mr. Watson, come here! I want you!" Mr. Watson, who was at the receiver in another room, heard the words distinctly *coming from the receiver* and rushed in great excitement to tell young Bell that his invention was a success. Only a few months later, Bell conducted the first successful one-way long distance telephone test in the world from Brantford to Paris, Ontario — a distance of eight miles. His idea had come of age — the telephone was born.

Improvements in the telephone

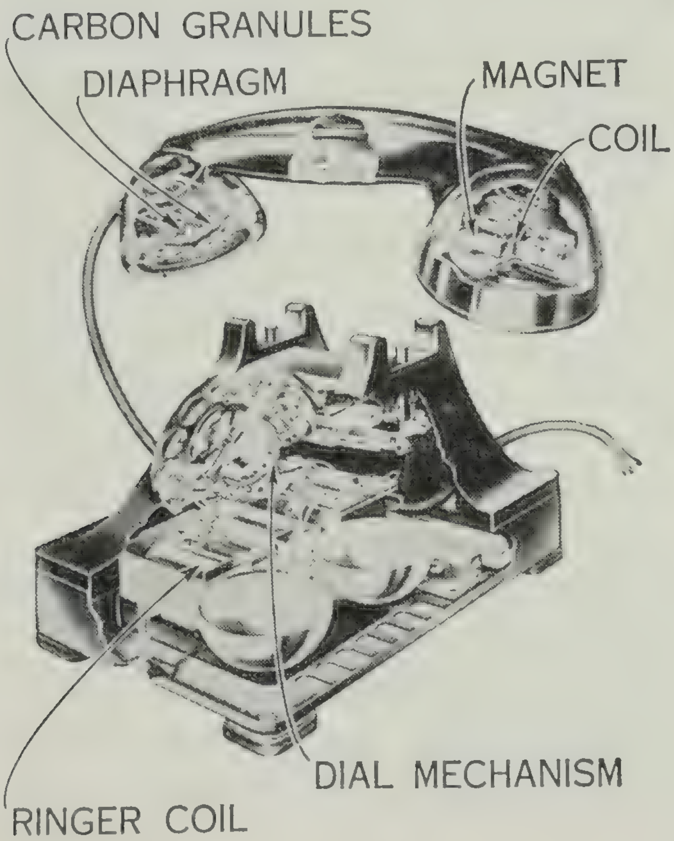
The year following Bell's discovery, Emile Berliner invented a loose contact *microphone*, the principle of which was soon used to advantage in the telephone transmitter. Further experiments opened the way to the perfection of long distance telephone communication. Today, you may talk with someone in a distant city, even as far away as London, England, and hear his voice as plainly as though it were coming from the house next door. Instead of using the services of a "long distance operator" to get you a number in a distant city, you can, in many cases, dial the number directly yourself.

Through the years, scientists have greatly improved the telephone. They

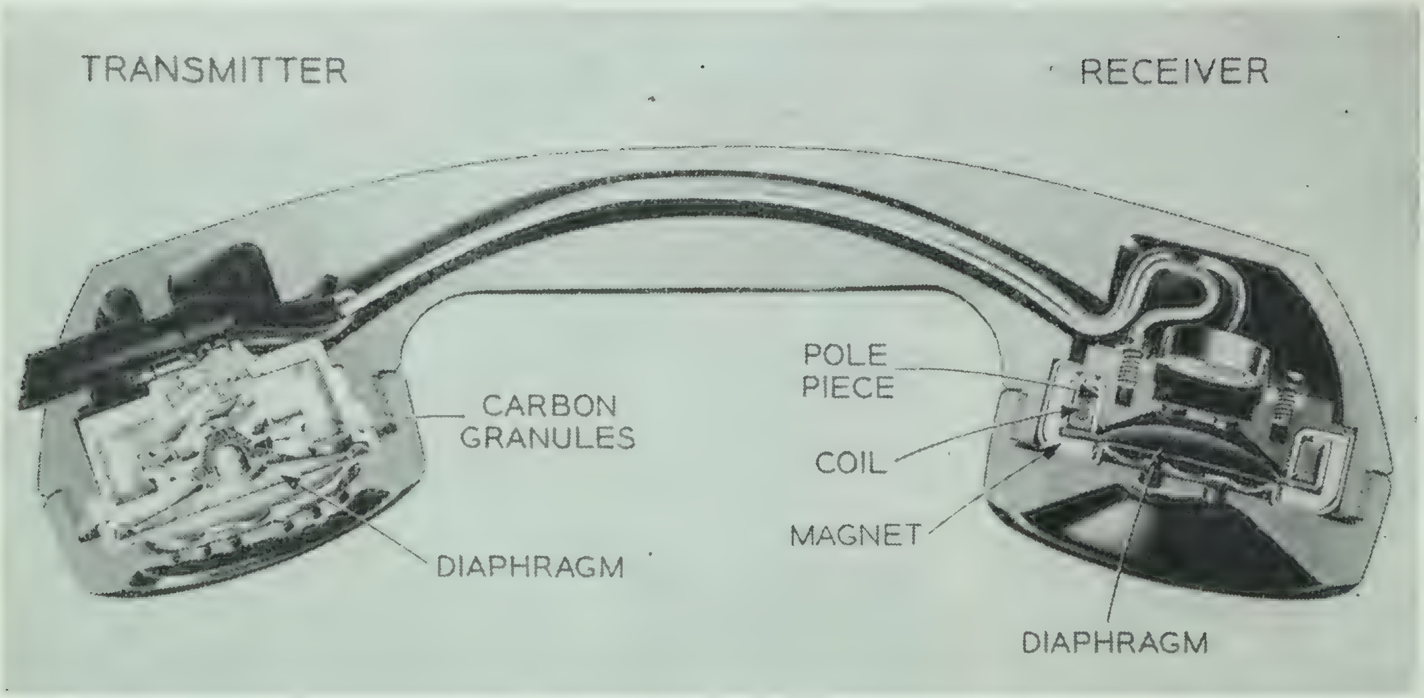
At the right is a typical tower along the 3800-mile coast-to-coast microwave network of the Trans-Canada Telephone System. Two huge antennae, shaped like giant sugar-scoops, are located on the top of the tower to relay the signals from tower to tower across the country-side. These radio relay towers are spaced about thirty miles apart, and provide a line-of-sight route over which telephone calls and television programs can be relayed great distances. The high-frequency radio waves, called microwaves, that do the work, travel in fairly straight lines like a beam of light. (Bell Telephone Company photo) →



have so perfectly developed effective methods of carrying many "voice currents" on a wire at one time that each listener hears only the voice intended for him. In some rural areas solar batteries, charged by energy from the sun, are being used to operate telephones. If possible, you should visit a telephone exchange to learn more about recent improvements.



← The drawing shown at the left illustrates the working parts of a telephone. Study the drawing carefully and compare it with the larger diagram of the speaker and receiver on page 182, and the telephone circuit on page 183.



The inside of a hand telephone set. Study this illustration along with the one shown on page 183. (Bell Telephone Company photo)

How does the telephone transmitter work?

Most boys and girls use the telephone to call their friends about numerous happenings. When you speak into the telephone transmitter, have you ever wondered how the instrument works? If you are curious about such things, you possess one of the attitudes of a scientist. To satisfy your curiosity, you should carefully examine a telephone transmitter to find out, first hand, how it operates.

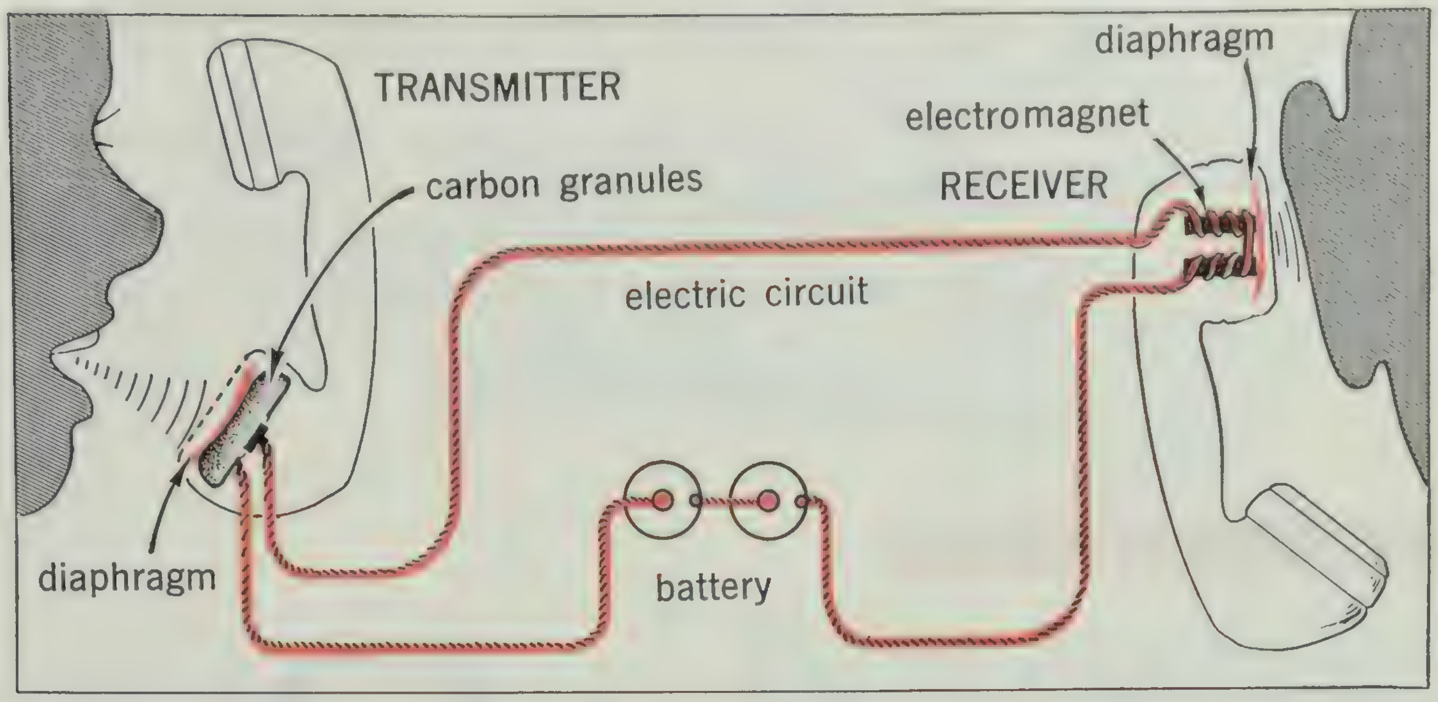
In making a study of the telephone, you should try to obtain discarded telephone transmitters and receivers for examination. These can be taken apart to disclose the main parts. They may be used, also, for experimenting.

One of the essential parts of a telephone transmitter is a *metal box filled with carbon particles.* Find it. Locate in the mouth-piece a *diaphragm* of light, flexible material.

The sound waves of your voice cause the diaphragm to vibrate. The vibrations pass through the box of carbon grains, and the carbon particles are alternately compressed and loosened by the vibrations. This process permits alternately stronger and weaker electric currents to flow to the telephone receiver. When you speak loudly, a stronger current passes through the transmitter than when you speak softly.

It is these variations in the current that make it possible, by use of a receiving apparatus, to hear sounds similar to those that entered the transmitter, whether it is situated in an adjoining office or in a distant country.

Do you see how the principle of the telephone transmitter is a direct application of Alexander Graham Bell's historic idea stated earlier in this section?



A simple telephone circuit. Trace the course of the electric current through the circuit. Explain how the listener is able to hear the message being spoken into the transmitter.

The telephone receiver

To learn how the varying electric current that travels along the telephone wires is able to reproduce the sounds that entered the transmitter, you should examine a telephone receiver. It is not difficult to find the essential parts.

SOMETHING TO DO

Arrange to borrow a *telephone receiver* from your local telephone company. Any receiver may be studied by carefully removing the hard rubber casing. Then you will be able to locate the main parts and the electric connections. Work carefully; do not damage the receiver.

A telephone receiver has two essential parts, an *electromagnet* and a *flexible iron diaphragm.* Find them in your receiver.

The stronger and the weaker currents coming from the transmitter cause alternately greater and lesser strengths in the electromagnet, which in turn cause vibrations in the diaphragm. The vibrations of the diaphragm produce sounds that are similar to those that entered the transmitter.

You will realize that the *sound* of your voice does not travel through a telephone system. What happens is that the sound is first changed into an electric current for transmission and is then changed back into sound.

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. Explain how the sounder of a telegraph set operates.
2. The telephone is an important contribution to communication made by a Canadian inventor.

(*a*) What was the inventor's name?

(*b*) What purpose is served by the diaphragm of the telephone transmitter?

(*c*) How are sound waves changed into a varying electric current in the transmitter?

(*d*) What are the essential parts of a telephone receiver?

3. What purpose is served by the electromagnet in (1) the electric telegraph and (2) the telephone?

ELECTRICITY IN MOTION

Not until scientists learned how to make electricity flow in a steady *current* could they put it to work. Electric currents were first studied by Volta, an Italian scientist who lived only a little over a hundred years ago.

Producing an electric current

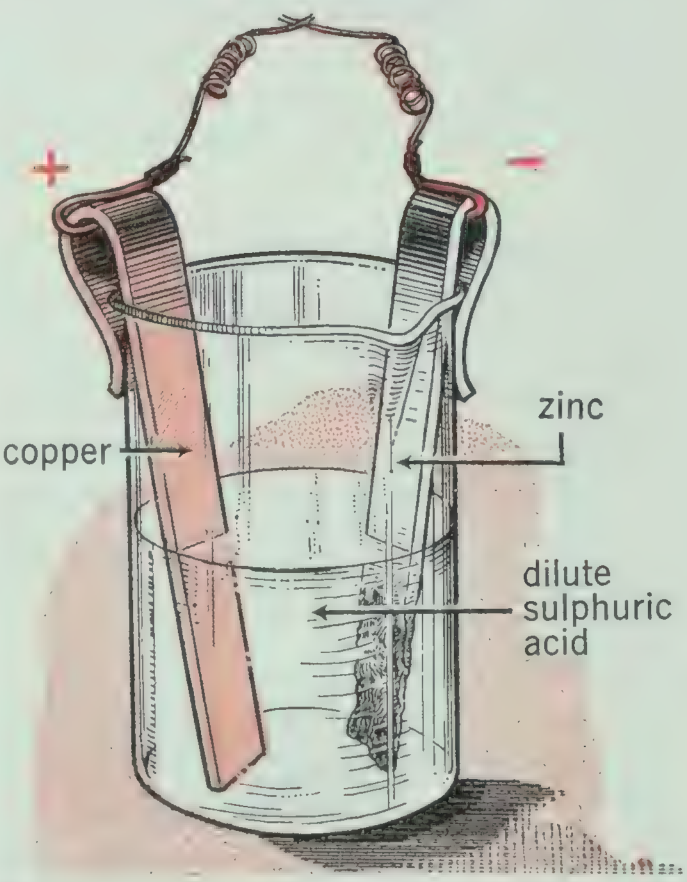
It is possible for you to produce an electric current by using materials similar to those that Volta used when he first studied current electricity. One method of producing an electric current by chemical action is outlined in the experiment that follows.

SOMETHING TO DO

Problem. — How can an electric current be produced?

Apparatus and Material. — Strips of zinc and copper about 1 × 4 inches (the copper may be secured from a local tinsmith, and the zinc from the metal cover of an old flashlight battery or the top of a fruit jar); concentrated sulphuric acid (to be obtained at a drug store); water; a glass tumbler; copper wire; a compass.

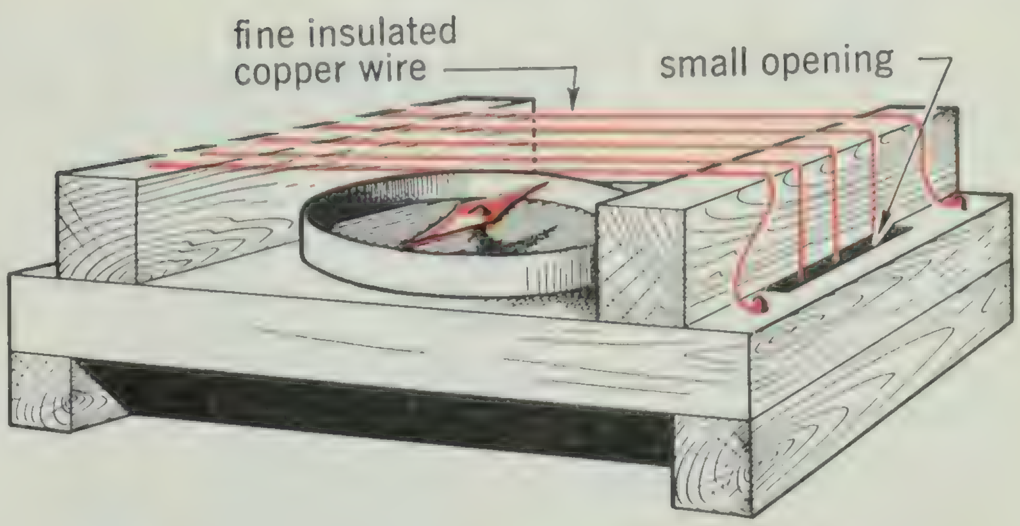
Method. — Into a tumbler about three quarters full of water, very carefully pour not more than $\frac{1}{20}$ as much sulphuric acid (estimate the right amount of acid in a second tumbler).



A simple zinc-copper electric cell. What is the source of this electric current? Use a compass to find if a current is flowing through the wire.

Caution: *You must be very, very careful in handling acid. It is dangerous, and, if spilled, will burn your clothes and hands. Always pour the* ***acid into the water;*** *never use the reverse procedure;*

Diagram of apparatus for detecting the presence of an electric current in a wire. Construct this home-made apparatus and use it for your electricity experiment.



it is dangerous to pour water into acid. It pays to be careful with acids.

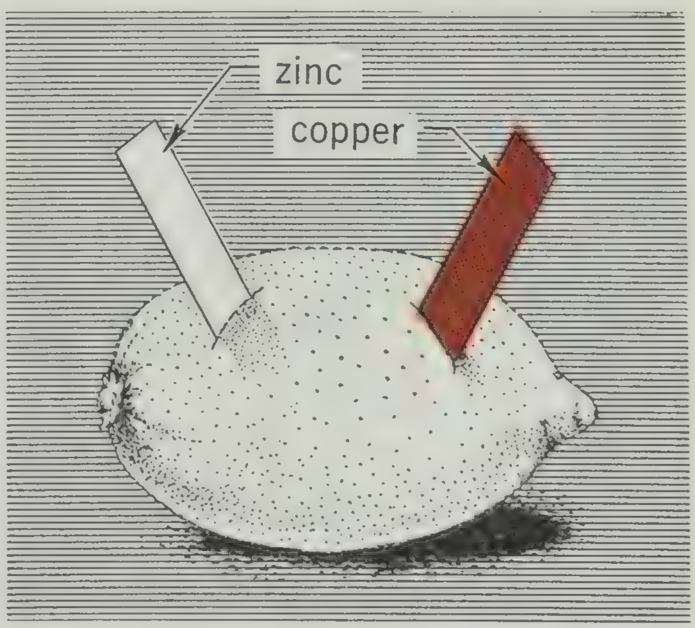
Attach a copper wire 3 feet long, to one end of the zinc; wrap the wire several times around the compass to make a coil parallel with the compass needle. Place the zinc and copper strips in the solution of water and sulphuric acid. Now firmly touch the free end of the copper wire to the copper strip. When you do this, what happens to the compass needle?

Observation. – Did you get an electric current when you placed the zinc and copper strips in the acid and before you connected the copper wire to the copper strip? When the zinc and copper strips were connected, did you get an electric current? How do you know? After the cell has been operating for ten minutes or more, try to find out which metal is being "eaten away" by the acid.

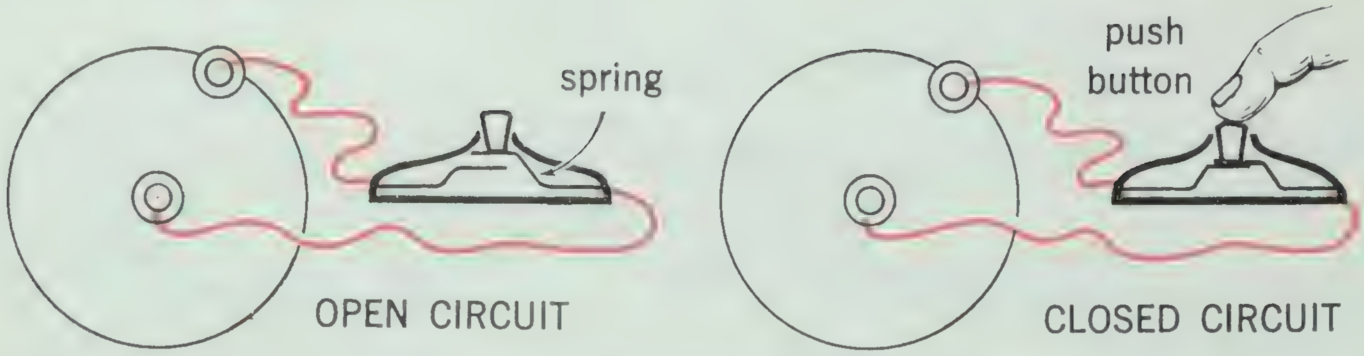
Conclusion.– Describe how an electric current can be produced. What parts of the apparatus and materials used in this experiment do you consider necessary to obtain a flow of electricity?

If you have followed the foregoing directions carefully, you have made *a simple electric cell.* It consists of *two strips of different kinds of metal,* or of a metal and some carbon, as we shall learn later, in a *conducting liquid,* such as sulphuric acid in water. The compass used in your experiment is not a part of the cell. It was simply used to detect the presence of the electric current.

When zinc and copper strips are placed in the diluted sulphuric acid of the cell, the acid begins to "eat away" the zinc. When the two strips are joined by a wire, the action of the



Try making this simple electric cell. What purpose does the lemon serve? Join the strips with wire and test for an electric current.



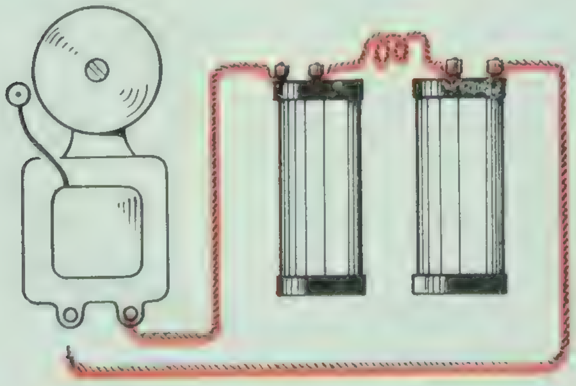
Left: An open circuit. Right: A closed circuit. Study the illustrations closely to learn why one circuit is open and the other closed.

acid on the zinc results in a flow of electrons, or an electric current, from the zinc to the copper. The copper is the *positive* or + pole or terminal, and the zinc is the *negative* or – pole or terminal. Study the diagram on page 184. This cell is often called the *voltaic cell.*

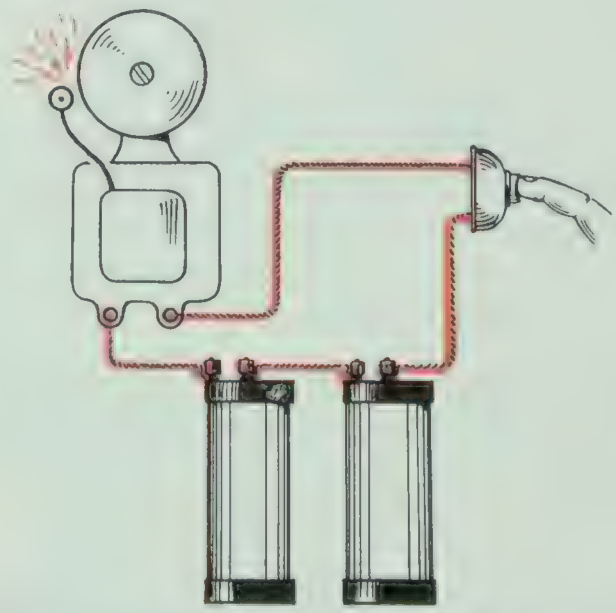
The simple zinc-copper electric cell is of little practical value, because the current very soon becomes too weak to ring a door-bell or do other work.

The electric circuit

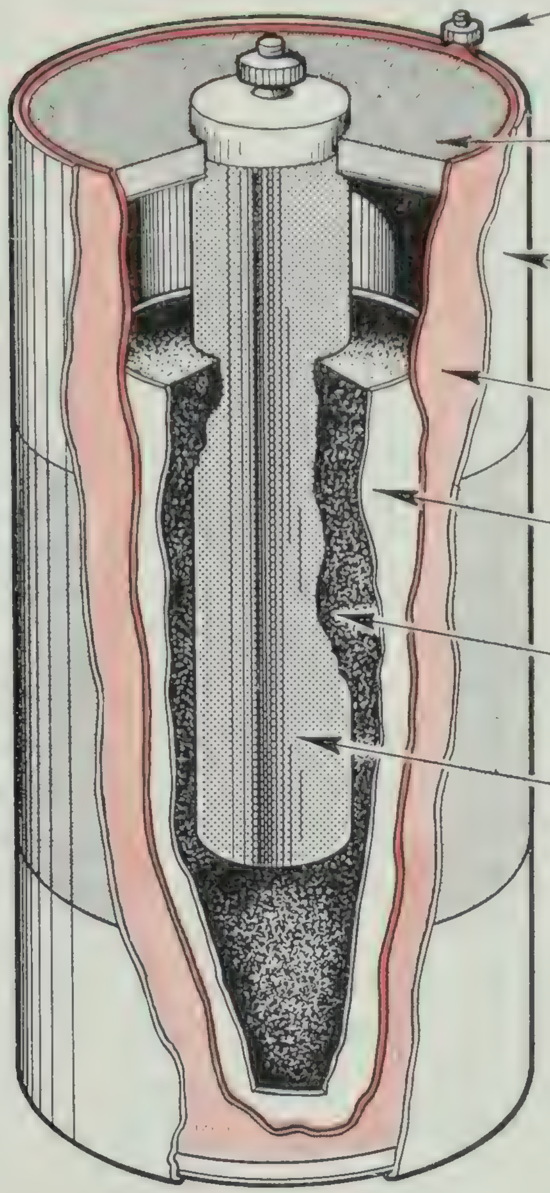
Your zinc-copper cell experiment, and what you now know about electricity, should make plain to you that an electric current will not flow out from a cell unless there is an unbroken path by which it can return to the cell again. There must be a complete pathway from one binding post of the cell to the other binding post. Such a path is called a *complete circuit.* Sometimes a complete circuit is called a *closed circuit.* When you switch on an electric light or ring a door-bell, you complete or close the necessary circuit so that electricity can flow to do its work. A break in the circuit, such as a disconnected wire, causes electricity to cease flowing. A *broken circuit* is said to be *open.* Push-buttons and switches are convenient devices for closing and opening electric circuits when we desire electricity to begin or to cease flowing.



This electric bell will not ring because two mistakes were made in hooking it up. Find the errors.



When the push button is pressed, the circuit is closed and an electric current flows through the circuit. Why does the bell ring?



The parts of a dry cell. Break open a used dry cell. Find the parts illustrated in this diagram. What produces the electricity in a dry cell?

Sometimes the circuit is completed by *grounding it,* that is, by *connecting it to a pipe driven into the earth or to a water pipe.* When wires are grounded, the earth takes the place of wire in part of the circuit. Damp soil is a conductor of electricity.

A dry cell

A cell that is commonly used for producing current electricity is the *dry cell.* It is not completely dry inside, as you might think from its name, but it has no liquid in it as other cells have, and therefore it can be carried in any position, as in a flashlight, for example, without there being any danger of spilling the materials within.

You probably know that the *battery* in your father's car is a *wet cell.* What must be added to this battery periodically to keep it operating efficiently?

SOMETHING TO DO

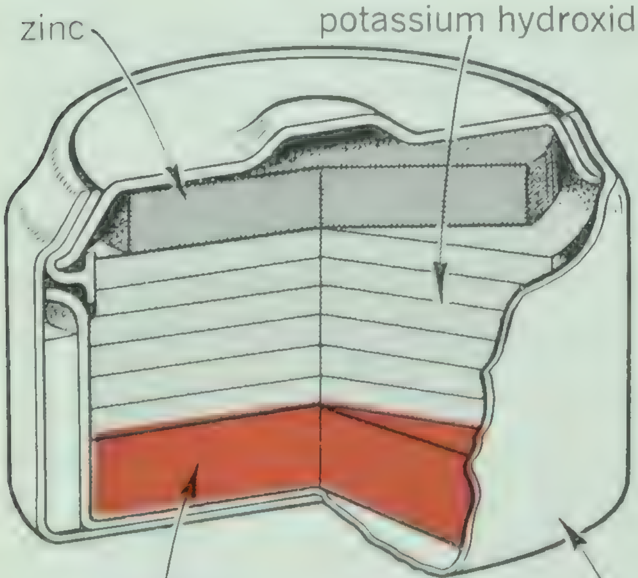
Take apart an old dry cell such as a flashlight battery. Find the parts as illustrated on this page. Notice particularly the *carbon rod* and the *zinc container.* Observe the black *mix,* which contains substances to help make the cell "work" well. Find the *pulp-board lining* between the mix and the zinc can.

The pulp-board lining of the dry cell is soaked with a paste of water and a chemical called *sal ammoniac;* an electric current is produced as a result of the action between the moist sal ammoniac and the zinc container. The zinc is "eaten away," and when holes appear in it, the cell becomes useless. The top of the cell is sealed to prevent the paste from drying out. The carbon, or centre terminal, is called the *positive pole;* the zinc, the *negative pole.* They may be marked + and −.

Be sure that dry cells are safely disconnected after they have been in use. The cells will be ruined if left connected for too long at one time.

Mercury cell

Another type of cell in which chemical energy is changed into electrical energy is the *mercury cell.* The materials in the cell that are involved in changing chemical energy into electrical energy are: (1) *zinc,* (2) *mercuric oxide* to which a small amount of graphite is added, and (3) *potassium hydroxide* (as is illustrated in the diagram at the bottom of this page). There are several types of mercury cells, each of which is suited to a different purpose. No chemical reaction takes place until the cell is connected up in a closed circuit; then the cell produces electrical energy for instant use.



A mercury cell, in which chemical energy is changed into electrical energy.

The mercury cell has a number of advantages over other chemical cells in common use, such as the dry cell: (1) It delivers a uniform output of electrical power throughout the life of the cell. This uniform power is due to the fact that the electrical pressure, or voltage, and the current strength, or amperage, remain constant. This makes the mercury cell an ideal source of power for use in transistors. (2) It delivers a large amount of electric power in relation to its size and weight. For this reason the mercury cell is adapted for use in small instruments such as inconspicuous hearing aids. (3) It has the ability to operate over a wide temperature range. (4) Its efficiency is not affected by long storage periods, by vibration and shock, or even by temporary overloads or short circuits. (5) The common mercury cell has a constant voltage of 1.34 volts.

Because of these advantages, mercury batteries are to be found in portable instruments used for communication, such as portable radios and radio transmitters; in photo flash guns; in pocket recorders; in guided

missile control equipment; and in many other scientific instruments. It is likely that the uses of the mercury cell will increase in variety and number in future years.

What is an electric battery?

An electric battery consists of two or more electric cells, such as dry cells, connected together to work as a unit. There are two common ways in which cells are connected. (1) In a simple storage battery such as an automobile battery, three or more storage cells are connected in *series*, that is, the positive pole of one cell is connected with the negative pole of the next cell, and so on (see diagram on page 175). (2) Cells may be connected in *parallel* by running two wires parallel to each other and connecting the positive pole of each cell to one of these wires and the negative pole of each cell to the other wire. (See diagram on page 172).

SOMETHING TO DO

1. Examine a storage battery such as is used in automobiles. How many cells does it contain?
2. Observe a garage attendant adding distilled water to a car battery. How do you know that the cells of the battery are separate?

Producing large supplies of electricity

In the preceding sections you have learned how an electric current may be produced by means of chemical action. The simple electric cells that you studied would not be practical however, to light our homes, to operate large machines in our factories and elsewhere in our environment, and to supply the large amounts of electrical energy required for our communication and transportation systems. The methods used to produce large supplies of electricity to meet these and other important needs will be considered in the next chapter.

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. Describe a method of determining whether an electric current is flowing through a wire.
2. What are the essential parts of a simple electric cell?
3. Make a labelled drawing of the simple voltaic cell that you helped to make and operate.
4. Electricity will flow through a closed circuit but not through an open one. What is the meaning of "closed" and "open" in this use?
5. By means of a carefully labelled diagram, show the structure of a dry cell.
6. How is electricity produced in a dry cell?
7. Why are dry cells more convenient than wet cells, such as the battery in an automobile?

WHAT HAVE YOU LEARNED?

IMPORTANT SCIENCE IDEAS AND UNDERSTANDINGS

A

1. Static electricity is produced by friction.
2. Lightning is a discharge of electricity built up in clouds.
3. An electric current consists of a flow of electrons through a conductor. It will flow only if the circuit is complete or closed.
4. There is a magnetic field around a wire carrying an electric current.
5. An electric voltage is produced in a conductor that cuts through a magnetic field.
6. Electricity can be used to produce magnetism, and magnetism can be used to produce electricity.
7. A simple electric cell consists of two strips of different kinds of metal and a conducting liquid that acts chemically on one of them.
8. Electricity can be produced by chemical action in which chemical energy is changed into electrical energy.
9. An electromagnet consists of a core of soft iron, or an alloy, around which are wrapped many turns of insulated wire. It behaves as a magnet only while electricity is flowing through its coil.
10. The strength of an electromagnet depends upon the number of coils and the strength of the current.
11. In a telephone transmitter, the sound waves that enter it are changed into an electric current that varies in strength. The varying electric current is carried over the telephone wires to the receiver, where it is changed back into sound waves that are similar to those that entered the transmitter.
12. Telegraph, telephone, radio, and television messages are transmitted at the rate of 186,000 miles per second, which is also the speed of light.

(a) The foregoing sentences are all true statements of important science ideas and understandings. Read and discuss them carefully as a review of this chapter.

(b) The sentences on the following page describe situations in which some of the ideas outlined in A, above, apply. To test your ability to apply ideas to actual situations, match sentences in A with situations in B to which they apply.

B

1. Peter Stevens put a strip of zinc and one of copper into a tumbler of water to which a little sulphuric acid had been added. He found that when he connected the zinc and the copper strips, an electric current flowed through the wire.

2. Marilyn Patton owned a strong magnet. One day she made a coil of insulated copper wire of sufficient size that one pole of the magnet could be thrust through the middle. She removed the insulation from the ends of the wire, joined these ends, and placed the wire over a compass. She then thrust the magnet quickly through the coil and noted that the compass needle was deflected to one side. She jerked the magnet out quickly and noted that the compass needle was deflected again, but in the opposite direction.

3. On her way to school, Linda Goodman noticed some birds sitting on a powerline. She knew that a man had been killed by touching a "live" wire while standing on the ground, so she wondered why the birds were not electrocuted.

4. When Earl Crosby called on Walter Emery, he pressed the push button of the front door-bell, but the bell did not ring. When the boys investigated, they found that the flow of electricity had been stopped by a break in the circuit caused by a broken wire.

5. Bill Curtis lives in Toronto. His grandmother lives in Vancouver. Bill called his grandmother by long distance telephone to wish her many happy returns of her birthday. He was able to carry on a conversation just as easily as if they had both been in the same

An electrician wiring a new home. Notice that all the wires are insulated. Why is this necessary?

room. Actually, his grandmother was 3000 miles away, and sound travels at a speed of only 1100 feet per second.

6. When Fred Blake entered his bedroom at night, he flipped the switch near the door and observed that his room was immediately flooded with light.

7. Michael Voss tested a large nail with a compass and found that the nail was not a magnet. Then he wrapped an insulated copper wire around the spike and connected the free ends of the wire to the poles of a dry cell. He tested the spike again and found that it repelled one pole of the compass needle.

IMPORTANT SCIENCE TERMS

A

static electricity	closed circuit	telegraph key
current electricity	open circuit	telegraph sounder
electrons	dry cell	telephone
electroscope	dynamo	microphone
conductor	electromagnet	telephone transmitter
electric cell	insulation	diaphragm
positive pole	electric bell	varying electric current
negative pole	electric telegraph	telephone receiver

To show that you understand and can use the science terms listed in A, match with the situations described in B those terms which apply.

B

1. During an electric storm in summer, Donna Kubo and Mary Novack watched the lightning. They saw it jump from cloud to cloud and from cloud to earth.

2. Yvonne Carter reported that she had read in a science text that an electric current can be produced by causing a coil of wire to rotate between the poles of a strong magnet.

3. A caller pressed the push button in the door-bell circuit of Mrs. Dupont's home. Mrs. Dupont immediately heard the bell ring and went to the door.

4. When he made his telegraph set, Gerald Gingerick knew that he must form the coil of the electromagnet by using wire covered with rubber or other material that will not conduct electricity.

5. Benny Rosen broke open a worn-out flashlight battery. Inside, he found, among other parts, a pulp-board lining. He later learned in school that the pulp-board is soaked with a mixture of water and sal ammoniac. Benny also found out that electricity is produced by the chemical action of moist sal ammoniac on the zinc container.

6. When studying the parts of a telephone receiver, Tony Romano and Paul Duchesne found a part that vibrates to produce sounds.

7. The copper plate of a simple voltaic cell and the carbon rod of a dry cell both form the same pole of the electric circuit.

SCIENTIFIC METHOD AND ATTITUDES

1. Ruth Kelly and Janet Brown had observed the small electromagnets in electric bells, telegraph sounders, and telephone instruments. They had also visited the local power plant and had seen the large electromagnets used in the generators. They had seen huge electromagnets pick up tons of scrap iron and load it onto railroad flat cars. They thought about what they had seen and realized that electromagnets vary greatly in strength. "What does the strength of an electromagnet depend on?" asked Ruth.

Outline how you would proceed to solve this problem by the scientific method as described on page 14. Be sure to include at least one experiment in your method. Also, be careful not to vary more than one factor or condition at a time when making a test. Why is this precaution important?

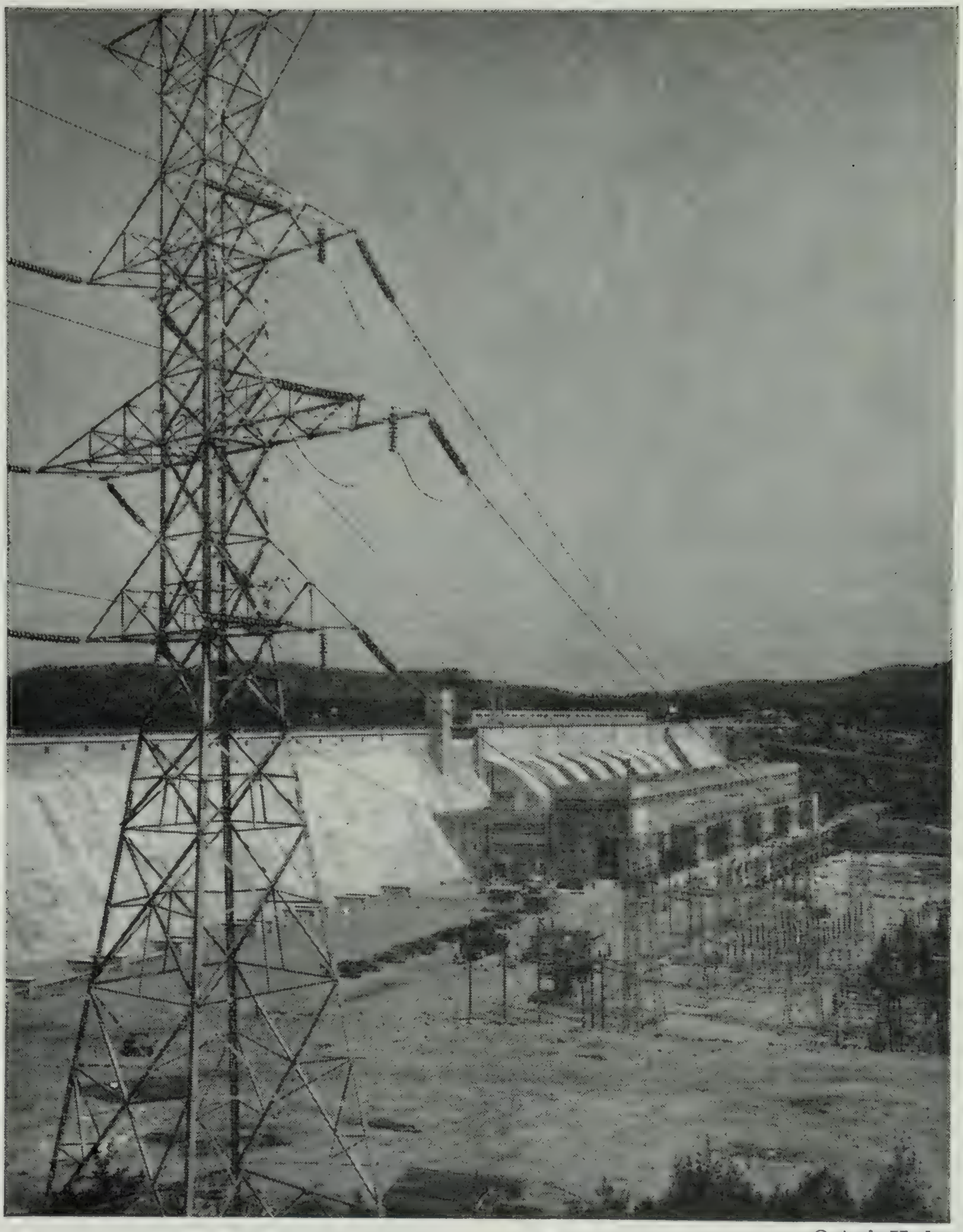
2. About 400 years ago, people believed the superstition that storms were caused by evil spirits. Passages from the Bible were read outdoors during storms to turn away the wrath of the evil spirits. Explain what science has done to show that lightning and thunder, like every other thing that takes place around us, do not just happen and are not produced by evil spirits, but are the result of natural causes or conditions.

3. A boy was experimenting with an electric bell. He connected it to a dry cell by means of insulated copper wire. When the bell did not ring, he at once concluded that the dry cell was worn out, and secured a new one. But still the bell did not ring. Then another boy discovered that there was a loose connection in the bell. After this had been repaired, the bell rang when again connected to the first dry cell.

(*a*) Wherein did the first boy fail to make use of the scientific method to solve his problem?

(*b*) Before jumping to the conclusion that the dry cell was dead, the first boy should have tested all the possible reasons why the bell did not ring. Make a list of the reasons that he should have tested.

(*c*) Outline the procedure that the boy might have followed in solving his problem in a scientific way.



Ontario Hydro

It leaps the sea, it spans the plain;
On throbbing wire and mighty chain,
It runs like fire from main to main,
That the world may see and know.

CHAPTER 5

CHAPTER 5

PRODUCING AND USING ELECTRICITY

Modern rapid communication is dependent on electricity. Electricity helps us with our work, and provides us with numerous comforts and conveniences. How can electricity be produced? A visit to a large modern power house with its huge electric generators is a very interesting experience. What is the source of energy for urban or rural electrification in your locality? What are some of the chief uses of electricity in your home?

To be able merely to push a button and immediately to have at one's service almost unlimited energy would have been regarded at one time as magic, and the person who practised the magic would have been looked upon with awe and perhaps even with fear. Today, this form of magic is practised so constantly by so many people that we scarcely give it a thought.

A waterfall is "harnessed" to produce electrical energy, and what wonderful results follow! Buildings are flooded with light. Electric stoves, washing machines, sweepers, irons, and other conveniences do much of the work in our homes. Trolley buses carry thousands of passengers through a city's streets. A switch is closed, and a huge electromagnet lifts a ten-ton load of iron. Disease is located and treated by means of powerful X-rays. A telegrapher taps a key, and a message is sent to a place hundreds of miles away. The Queen speaks to us from London, England, and we hear her in Canada as distinctly as if she were in the same room. In our living room, by means of television, we can have a front-row seat at a ball game, an opera, or an important news event that is taking place thousands of miles away. Without electricity, none of these things would be possible. Yet it was only a little over a hundred years ago that men began to find ways of putting electricity to work.

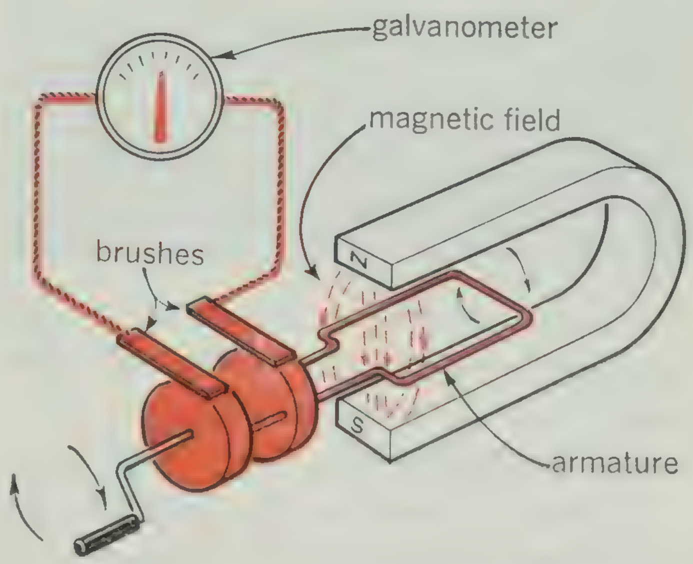
ELECTRIC GENERATORS AND MOTORS

In Chapter 4 you learned that chemical cells such as the simple Voltaic cell, the dry cell, and the storage battery can be used to produce electrical energy. The process involves the changing of chemical energy into electrical energy. This is what always happens when electrical energy is produced — another form of energy is converted into electrical energy.

When electrical energy is to be produced on a large scale, electric generators are used. These may be installed in hydro-electric power installations or in steam-generating plants. In hydro-electric plants the energy of falling water is converted into mechanical energy, which in turn is converted into electrical energy. In the steam-generating power plant the chemical energy of the coal, oil, or gas that is used as a fuel is changed into heat energy; the heat energy is changed into mechanical energy, and the mechanical energy into electrical energy. In an atomic electric-power plant, heat energy is changed into mechanical energy, which in turn is converted by electric generators into electrical energy. You will learn more about this transformation of energy as you study the sections in this chapter on electric power installations.

How electric generators operate

The use of electricity for lighting and for power was not practical until scientists invented and improved the electric generator, or *dynamo*. The principle on which the dynamo operates was discovered by a great scientist, Michael Faraday, of whom we shall learn later. Faraday found that thrusting a pole of a permanent magnet into a coil of wire that was properly arranged caused an electric current to flow in the wire. From this experiment and others, it was learned that *whenever an electrical conductor is made to cut a magnetic field, electrical voltage is produced.* The size of this electrical voltage depends upon the *speed* at which the magnetic field is cut. This voltage is like the pressure in a water pipe that causes a stream of water to flow if a tap is opened. If the circuit between the ends of the moving conductor of an electric generator is completed by a conductor, the voltage causes a "stream of electrons," or an electric current to flow.



A simple dynamo, or electric generator. Find the armature, the permanent magnet, the two slip rings, and the two brushes. Explain how this generator works.

A simple electric generator, or dynamo, has three essential parts: (1) the *armature*, which consists of a coil of insulated copper wire wound around a soft iron core; (2) a *magnet*, which supplies the magnetic field; (3) two *slip rings* mounted on the same shaft as the armature (see diagram on page 197). Each end of the armature coil is connected to a slip ring. The electric current that is generated is collected by means of two *brushes*, one of which rubs on each slip ring.

The armature of the dynamo is made to rotate by some external force such as that supplied by steam or gas engines or by water wheels or turbines. This causes the electrical conductor (copper wire coil of armature) to cut through the lines of force of the magnetic field. You have already learned that whenever this happens an electric voltage is produced, which causes an electric current to flow through a closed circuit.

In some generators the magnet rotates around a stationary armature instead of the armature rotating between the poles of a stationary magnet. Essentially the same conditions obtain in both cases, namely, an electrical conductor is caused to cut through a magnetic field, with the result that an electric voltage is generated in the conductor.

Depending on their design, generators produce either a *direct current* or an *alternating current*. A direct current (D.C.) flows only in one direction. The current from a storage battery is an example of a direct current. An alternating current (A.C.) reverses its direction rapidly. This is the current most used in our homes.

SOMETHING TO DO

Dismantle an old generator to find the main parts. A generator used in an automobile or for providing light on a bicycle would serve the purpose.

The story of Michael Faraday

In 1831, Michael Faraday, a great English scientist, made a very important discovery, which resulted in the development of the *dynamo*, or *electric generator*. As you learned in the preceding chapter, other scientists had found that magnets can be made by using an electric current. It occurred to Faraday that it should be possible to reverse the process, that is, to produce an electric current by the use of magnets. After ten years of experimenting, he discovered that if he moved a magnet in and out of a coil of wire that was properly arranged, an electric current would flow through the wire of the coil. From this discovery came the invention and development of the huge dynamos that are now so widely used to generate electric energy for light, heat, and power.

Michael Faraday ranks as one of the greatest scientists of all times. Few men have added more to the sum of human knowledge than he did.

The son of poor parents, Faraday, at the age of twenty-one, was a news-

Ten large electric generators in a power plant at Niagara Falls. Compare the size of the generators with the men shown at the left. Each generator is operated by a water turbine directly below it. What is the source of the energy that turns the turbine wheel? (General Electric Company photo)

Michael Faraday, the inventor of the electric generator, experimenting in his laboratory. (International Nickel Company of Canada)

boy and a book-binder's apprentice, but he longed to be a scientist. Through the kindness of a friend, he was privileged to attend a number of lectures on science given by Sir Humphry Davy, one of the leading scientists of that time. Faraday took notes, while he listened to the lectures, and made drawings of the apparatus used in the experiments. Later he sent his book of notes and drawings to Davy with a letter telling of his great desire to study science. A few weeks later, to Faraday's surprise and joy, a splendid carriage drew up at his door, and a servant delivered a message from Davy offering Faraday the position of assistant in his laboratory.

For Faraday, this was the beginning of over fifty years' work in science. In all, he performed more than 16,000 experiments. In addition to his discovery of the dynamo, he made many other important contributions to science. With Davy, he invented the safety lamp used by

miners. Later he succeeded in turning to liquid all but six of the gases then known to science. He also discovered benzine.

Ten years after his discovery of the principle of the dynamo, Faraday's health failed. He was pensioned by the British government and honored in many countries. Not only was Faraday a great scientist, but he was a true gentleman, quiet and unassuming. When he died in 1867, a friend paid tribute to him in the following epitaph: "Just and faithful knight of God."

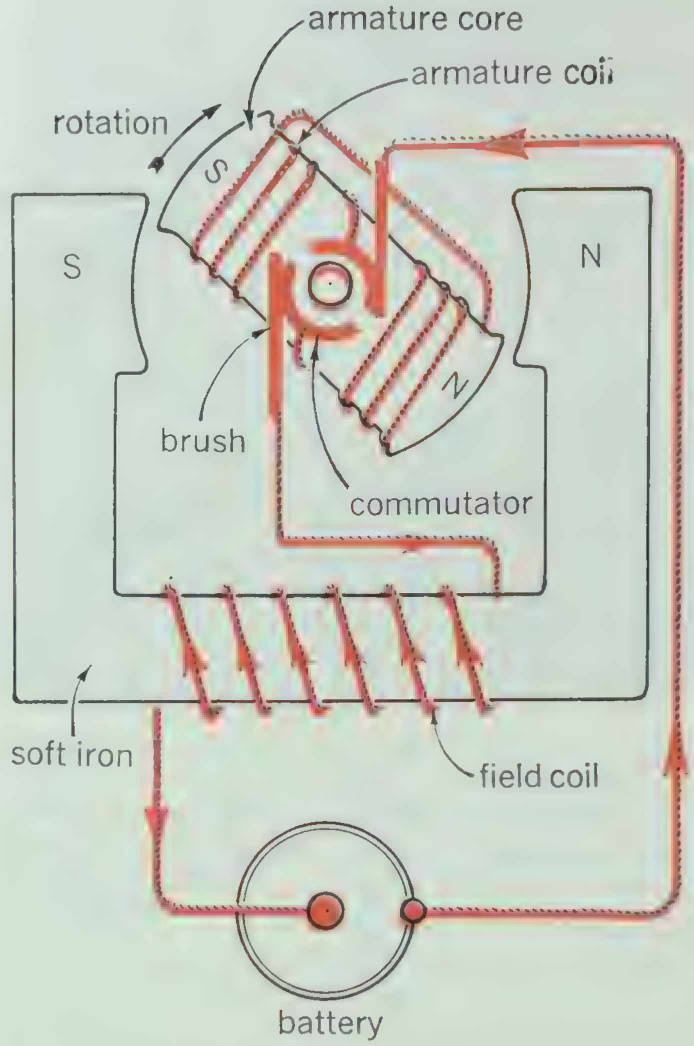
Faraday's discoveries helped to make many changes in our ways of living.

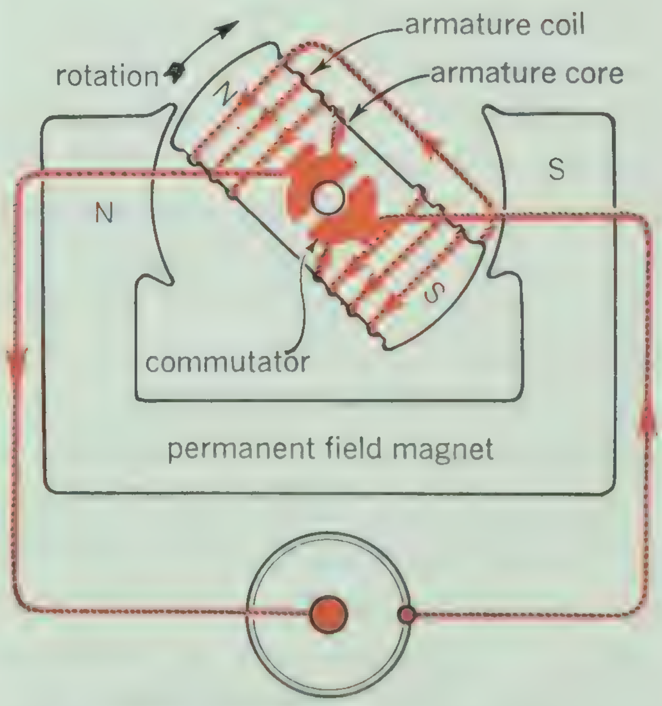
A simple electric motor

An electric motor is a machine designed to change electrical energy into energy of motion or mechanical energy.

When electrical energy is supplied to the motor, the shaft of the motor rotates; electric energy is changed into mechanical energy (energy of motion). This is the reverse of what happens in an electric generator where mechanical energy is changed into electric energy. Electric motors are used in homes to operate vacuum cleaners, sewing machines, washing machines, electric mixers, electric refrigerators, electric floor polishers, and other conveniences.

Study the diagrams of electric motors shown on this page. Note that one electric motor consists mainly of two *electromagnets* and a *commutator*.





Top: An electric motor made with two electromagnets. Most powerful motors are of this type. Bottom: An electric motor made with one electromagnet and one permanent magnet. Trace the path of the electric current in each kind of motor. Explain why the armature rotates in each motor.

Parts of an electric motor. What parts can you identify? (Canadian General Electric photo)

In the other electric motor, a permanent magnet is used instead of one of the electromagnets.

To understand how an electric motor operates, you will need to recall that *like magnetic poles repel, and unlike magnetic poles attract*. Bearing this important scientific truth in mind, explain why the armatures of the electric motors in the diagrams on page 200 are shown to be rotating in a clockwise direction. In other words, what forces would cause the armatures to rotate that way?

At any stage in the rotation of an armature there are two instances of attraction and two of repulsion. What are they? All of these forces work together in causing the armature to turn in a certain direction.

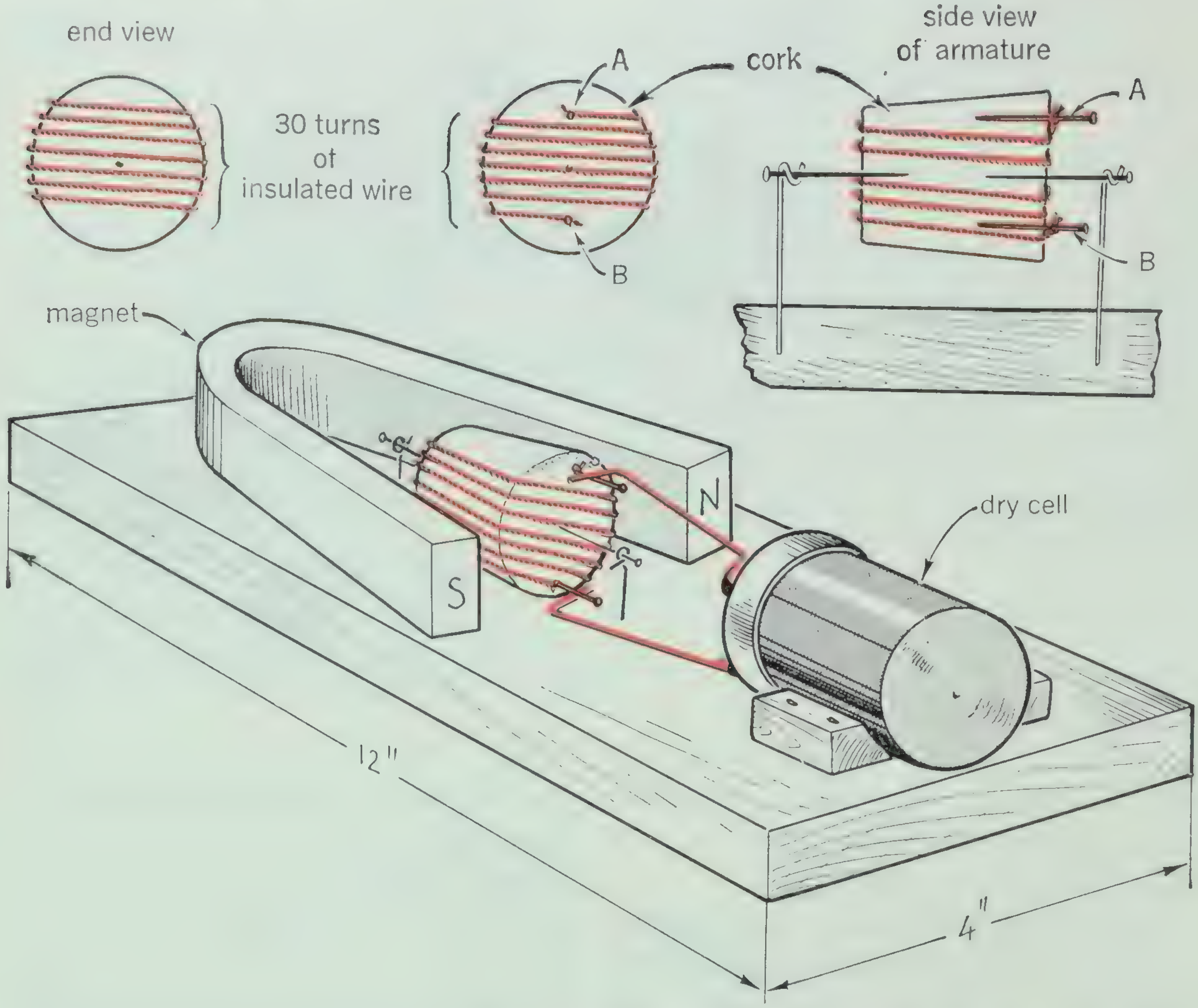
When the armature reaches a certain position, the brushes slip from one segment of the commutator to the other. This reverses the direction of the electric current flowing through the coil and thereby reverses the polarity of the armature. By this means the armature is kept rotating steadily in the same direction.

SOMETHING TO DO

1. Construct and operate a simple electric motor.

Apparatus and Material. — A large cork, about 1″ x 1″; 10 feet of No. 28 insulated copper wire; 14 inches of No. 20 copper wire; four pins; a horseshoe magnet (Ford type); one flashlight dry cell (No. 2); a board about 1″ x 4″ x 12″.

Construction. — (1) Push a pin at right angles into the *centre* of each end of the cork. (See diagram on page 202). (2) Push the other two pins into one end of the cork at A and B, equal distances from the centre pin. (3) Remove pin A, and



Plans showing the construction of a home-made electric motor. Details for making and operating the motor are given on page 201 and on this page.

push the bared end of the long wire into the hole. Replace pin A so as to make contact with the wire. (4) With this wire wind a coil of about 30 turns lengthwise on the cork. (5) Remove pin B, and push the remaining end of the long wire into the hole. Replace pin B so as to make contact with the wire. The *armature* is now complete. (6) Make two holes near the centre of the board, the same distance apart as the heads of the first two pins that were placed in the cork centre. (7) Securely fasten a 3-inch piece of No. 20 copper wire in a vertical position in each of these holes. (8) Hold the armature against these wires, and about ¼ inch above the board. Wind one wire twice around one of the centre pins. Do the same with the second wire and the other centre pin. This will support the armature. (9) Fasten the dry cell to the board in a horizontal position and in line with the armature. (10) Attach a 4-inch piece of No. 20 copper wire to each terminal of the dry cell, and bend them so that they will serve as brushes on pins A and B. (11) Place the magnet in position and give the armature a spin.

NOTE. — If the armature does not continue to spin, you may have to make

some slight adjustments; for example, it may be necessary to lessen the pressure of the brushes on the pins.

2. While the motor is operating, take the magnet away from the armature. What happens? Why?

3. Replace the magnet in a reversed position. Does the armature rotate? Does it do so in the same direction as before?

4. Turn the dry cell slowly, first to the right, then to the left. Account for the results observed.

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. (*a*) Name the scientist who discovered the principle of the electric generator, or dynamo.
   (*b*) State the principle on which the dynamo operates.
2. Make a drawing of a simple electric generator and label the three essential parts.
3. Explain how a dynamo operates.
4. (*a*) What is the difference between a direct current and an alternating current?
   (*b*) Give one use of each type of electric current mentioned in (*a*).
5. Compare an electric generator with an electric motor with respect to: (1) important parts, (2) changes in energy while operating, (3) uses.
6. In your own words tell about Michael Faraday's scientific discoveries.

ELECTRIC POWER PLANTS

To obtain large supplies of electricity for use in homes and other buildings, in industry, transportation, and communication, huge power plants are required. In these power plants, the energy of running water or the energy in coal, oil, sunlight, or the atom, is changed into electric energy by means of electric generators.

Hydro-electric power

The modern type of water wheel used in hydro-electric power installations is called a *turbine*. In Canada and other countries, many rivers have been harnessed to furnish power for use in our homes and in our daily work. In water-power resources, Canada ranks second among the countries of the world. When the energy of running or falling water is used to assist us with our work, it is usually transformed into other forms. The chief of these forms is electric energy. Power plants that use water for their operation are built either near natural waterfalls, such as at Niagara, or beside large dams, such

Running water possesses energy. By harnessing waterfalls, man has been able to use their energy to do much of his work. (Ontario Department of Lands and Forests photo)

as those on the Gatineau and St. Maurice Rivers in Quebec, and on the Columbia and Colorado Rivers in the United States. The latter are, in effect, artificial waterfalls.

From the point of view of conservation of natural resources as well as of economy, water power, when it is available in abundance and on a reliable all-year-round basis, is the ideal natural source of power to harness for the production of electricity.

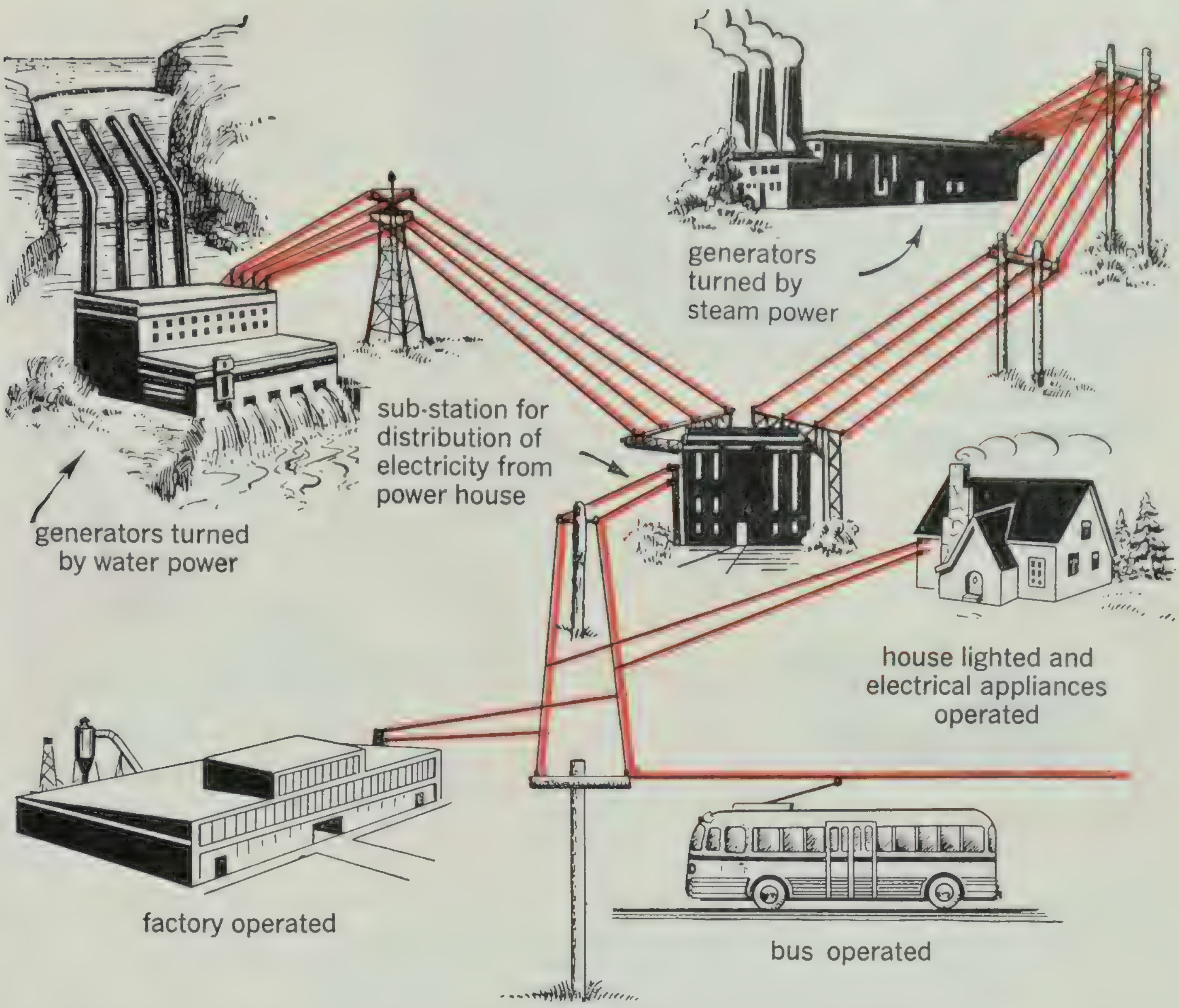
The never-ending cycle of the waters of the earth flowing to the sea, evaporating and returning to the land in the form of rain and snow, supplies man with a natural source of energy which is constantly being replenished through the effect of the sun's radiated energy. It remains for man to adapt this cycle to his needs by designing and building structures to control the rivers to attain a dependable year-round flow.

In power installations of this type, the modern water wheel or *water turbine* is always placed at the bottom of a large, nearly vertical water pipe called a *penstock* (see page 207). Water flows rapidly from the dam, or from the river above the waterfalls, through the penstock, to the turbine. The force of the falling water striking against the blades of the turbine causes the wheel to rotate rapidly. As the turbine is directly connected to an *electric generator* above it, the rotation of the turbine causes the generator to rotate and produce electricity. Study the illustration on page 205 so that you will have a better understanding of the way in which water power is changed into electric power.

In many cities, these water-power installations furnish electric power for transportation by trolley buses. The installations supply electricity to light our homes and to operate our electric stoves, washing machines, sewing machines, vacuum cleaners, floor polishers, refrigerators, shavers, and toasters. They also supply electric power for our factories, stores, amusement centres, schools, and churches.

SOMETHING TO DO

1. Visit a water-power installation in or near your locality. How many generators are in use? How much electric power is generated?



This diagram illustrates two methods of producing electricity: (1) a power house operated by water power; (2) a power house burning coal and operated by steam power. What method is used in your locality? Trace the electricity used in your home back to the power house where it is produced. (See pages 207, 212, and 215.)

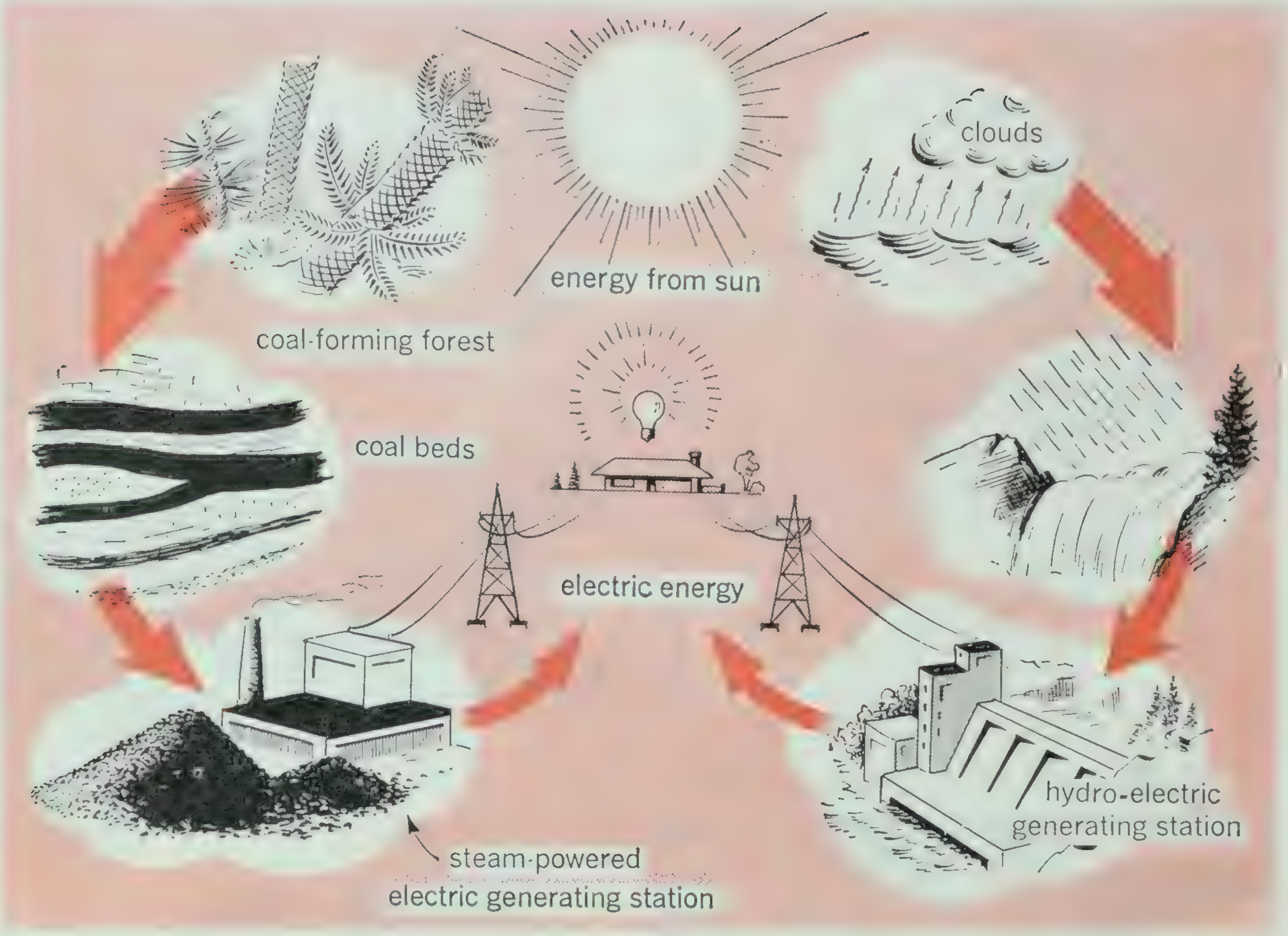
2. Find information about other large water-power installations in Canada, such as where they are located, what cities and rural areas are served by them, how many generators are present in each plant, what important industries are nearby, etc.

3. Try to find out to what extent the St. Lawrence Seaway project is linked up with the production of electric power for industrial and home uses.

4. Prepare a report for your class showing some of the more important industries that have been developed in Canada because of conveniently situated sources of water power.

Electric energy from coal and oil

In the preceding section, you learned that a water turbine is used to produce electric power. Waterfalls, either natural or artificial, are necessary for its operation. There are, however, large areas in Canada, the



Explain how energy from the sun is changed into electrical energy in two different ways.

prairies, for example, where few sources of water power for the production of electric power exist. In such areas, steam turbines are commonly used to operate electric generators. Coal and oil are burned to produce steam for these turbines.

The steam turbine was designed to give smooth, steady power for driving high-speed machines, such as generators for producing electric energy, and the propellers of ocean liners. Steam turbines are widely used today.

SOMETHING TO DO

1. Bring from home a toy steam engine. Find out how it works. Let each member of the class have a chance to operate it.

2. Into a container such as a test tube or a small bottle, pour water to a depth of about ½ inch. Stop the mouth of the container snugly, *but not too tightly*, with a cork or a rubber stopper. Heat the container until the water boils to form steam. What happens to the stopper? Does this show that steam possesses the power to do work? ***Caution!*** *Point the container away from people to prevent their being scalded by the escaping steam.* It is safer to secure the container before heating it, so that you can stand well back from it.

3. Construct a steam turbine. First obtain a thin sheet of tin and cut out a

Electric power from coal. In power plants like this, the energy present in coal is used to produce steam which in turn operates steam turbines. The turbines rotate electric generators, which produce electricity. In this way energy present in coal is transformed into electric energy. (Ontario Hydro photo)

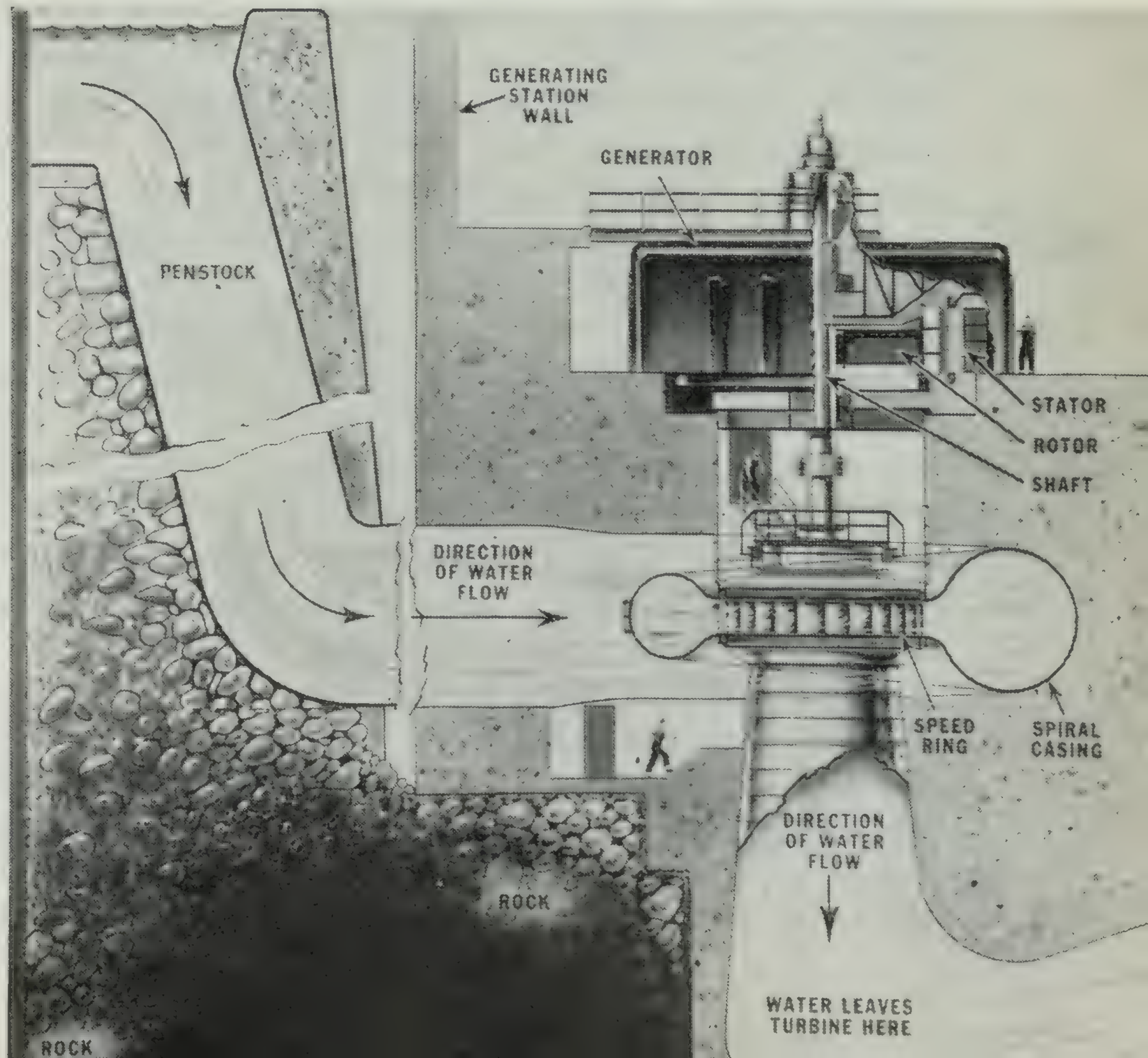
circular piece about 6″ in diameter. Using tin snips, or old scissors, make cuts 1″ apart, extending 1″ into the edge of the tin. Do this all around the circumference. Now twist each section of tin to form a vane (see illustration on page 208).

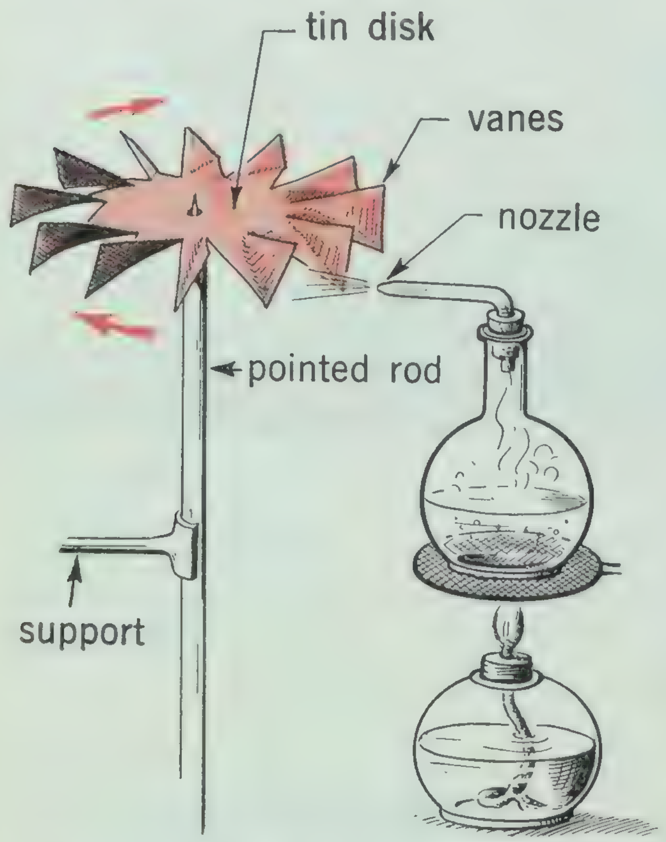
Make a small hole through the centre of the disk, which now represents a turbine wheel. Support the wheel on a large nail, pencil, or pointed stick.

Set up a steam turbine as indicated. It may be necessary to use more than one alcohol lamp to produce steam fast enough to turn the turbine wheel.

A steam turbine consists of a series of "windmill" vanes called *buckets,* set in wheels mounted on a shaft. They are so arranged that steam, instead of wind, can be directed against the

Water turbine and electric generator installation. Water flows from the dam through the large water pipe or penstock to the water turbine. The force of the water causes the turbine wheel to rotate. Note the shaft that connects the turbine wheel with the electric generator directly above it. Basing your explanation on what you have learned about the way in which a dynamo produces electric energy (pages 197 and 198), describe how the energy of falling water is changed into electric energy at a power plant such as the one illustrated here. (Canadian General Electric photo)





A steam turbine. What is the source of the energy that causes the turbine wheel to rotate?

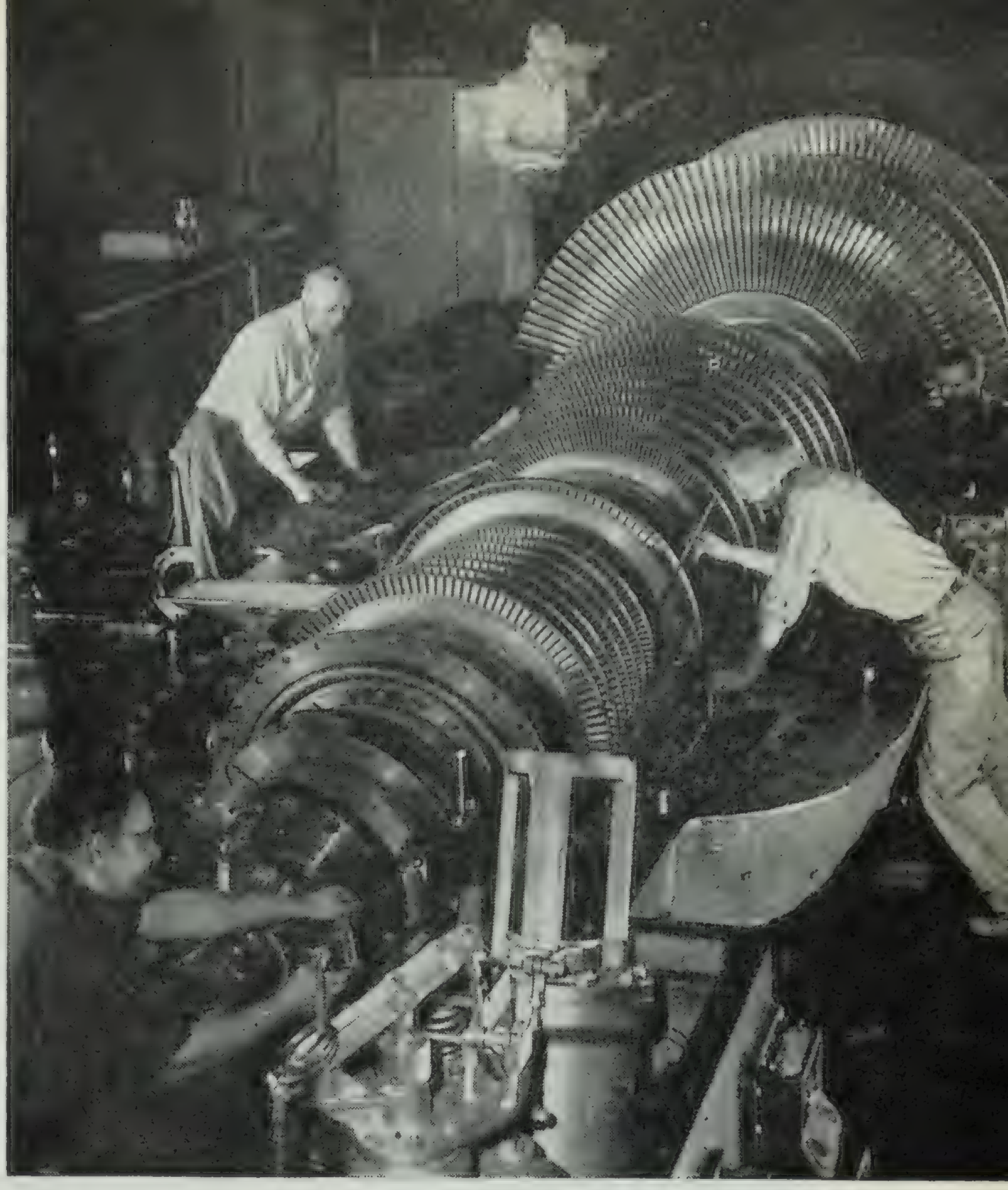
buckets, thereby causing the turbine shaft to rotate. The steam is under high pressure and blows at a speed of about 1200 miles an hour. It causes the turbine wheels to turn at a very high speed. Scientists and engineers worked for many years to design and develop turbines such as the one shown in the illustration on page 209. Thousands of experiments, tests, and accurate measurements were necessary to make certain that the materials and the construction would withstand the strain caused by the high speed of rotation.

The inside of a steam turbine has sometimes been referred to as "The Home of the Hurricane." In nature, a hurricane blows at a rate of about 140 miles per hour. But the man-made hurricane of hot steam in a modern turbine blows at over 1000 miles per hour — much faster than the speed of sound. This steam is different from the ordinary steam from a tea-kettle. The steam in a turbine is so hot that it would melt tin or burn a stick of wood in an instant.

This steam, under tremendous pressure, rushes into the turbine, passes through a ring of nozzles, and hits the first row of buckets with explosive force. From there, it bursts through a second set of nozzles and hits the second row of buckets, then continues on to the next row. The energy possessed by the steam is gradually expended against the rows of buckets, of which there may be twenty or more. The force of this pressure causes the shaft to which the turbine wheels are attached to rotate at very great speed.

The shaft of the steam turbine in an electric power plant is connected directly with an electric generator. The energy of the rotating shaft is passed on to the generator, which, in turn, changes it into electric power for lighting and industrial purposes.

The power that sends nearly all the world's famous passenger ships speeding across the oceans comes from steam turbines. They supply the power to turn the propellers that drive the ship forward. Turbines have been going to sea for many years. They have helped to set records for speed and economy in ships of many kinds, from giant luxury liners to small cargo ships and ferry boats. It



Engineers and workmen check a new steam turbine. They will test the turbine under various speeds with steam at varying temperatures and pressures, before installing it in a power plant. Note the series of vanes that are set in wheels mounted on a shaft. (General Electric Company photo)

is evident, then, that the steam turbine is an important aid to transportation in this modern age.

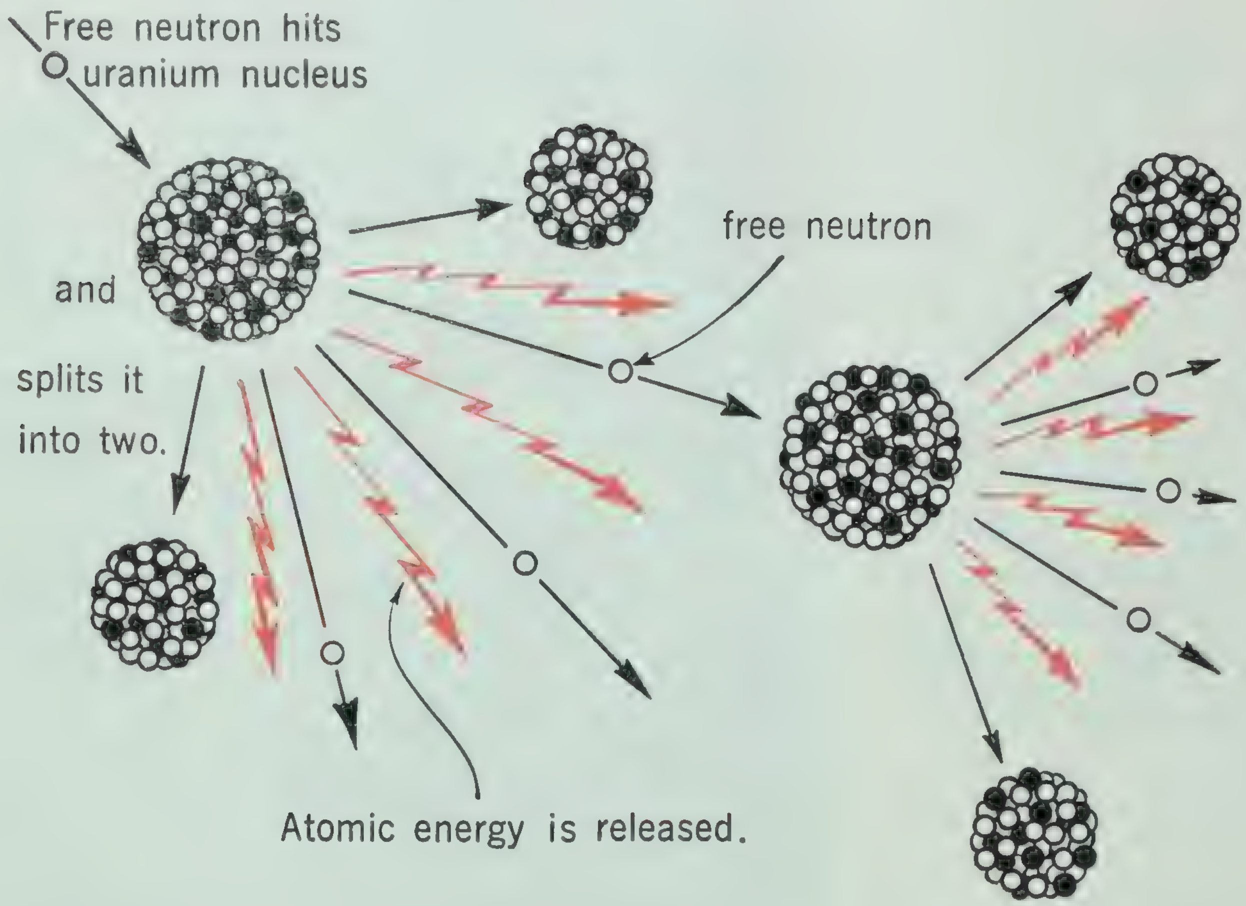
In some power plants, oil or gas is used instead of coal as a source of heat. As you have already learned, the heat energy present in these fuels is changed into electrical energy.

Producing electricity from atomic energy

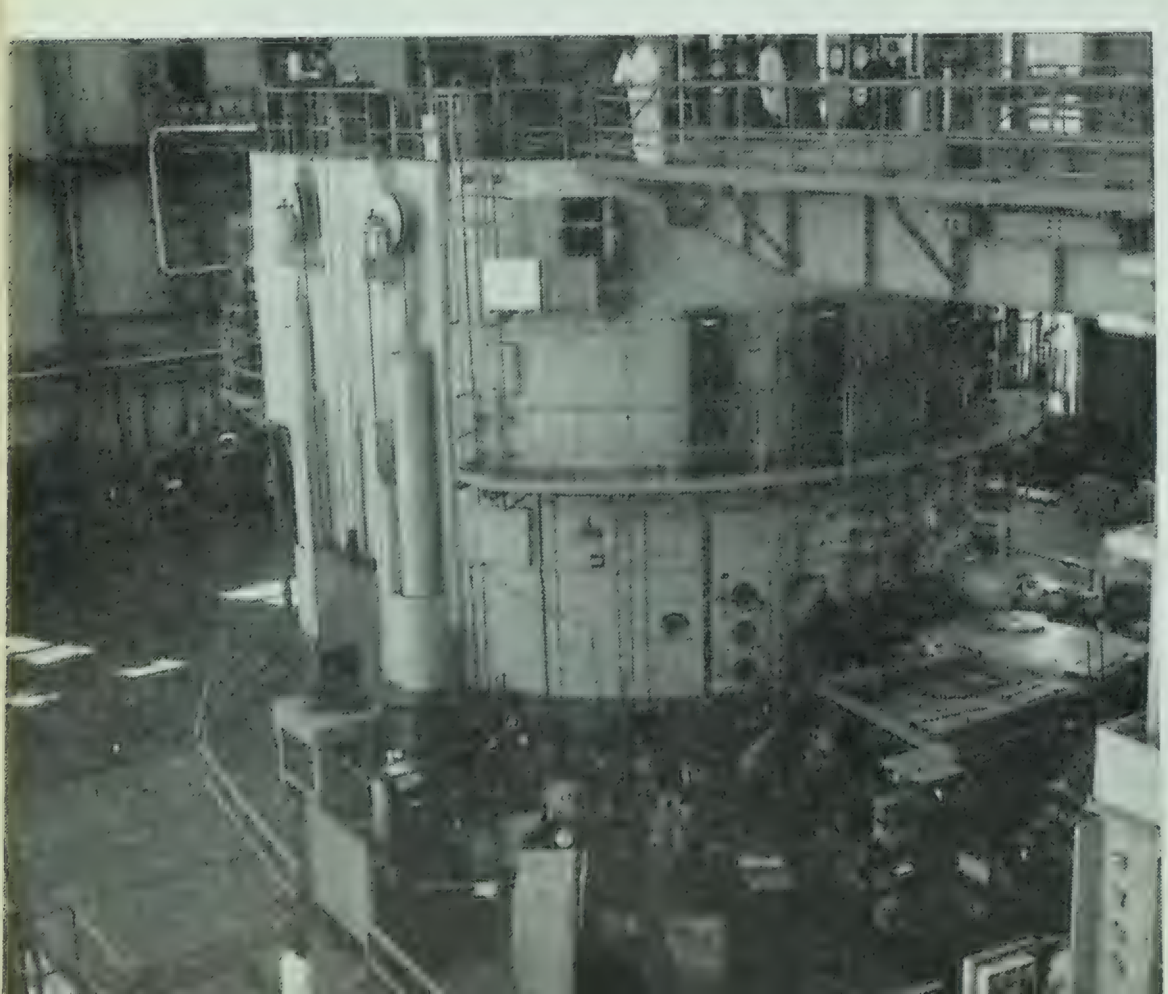
Atomic energy comes from the heart, or nucleus, of the atom. For this reason it is often called *nuclear energy*. It is a very powerful kind of energy.

Scientists have succeeded in splitting the nucleus of the uranium atom in two. The process is called *nuclear fission*. Neutrons are used as "bullets" to break the atom apart. When a nucleus is split, more neutrons are set free, and these strike other nuclei (plural of nucleus), setting free more neutrons to strike more nuclei, and so the process continues and spreads as a *chain reaction* (see drawing page 210). With the splitting of each uranium nucleus, a very large amount of energy is set free. This is the energy that we call atomic, or nuclear energy. It is this energy that scientists are trying to harness for the benefit of mankind.

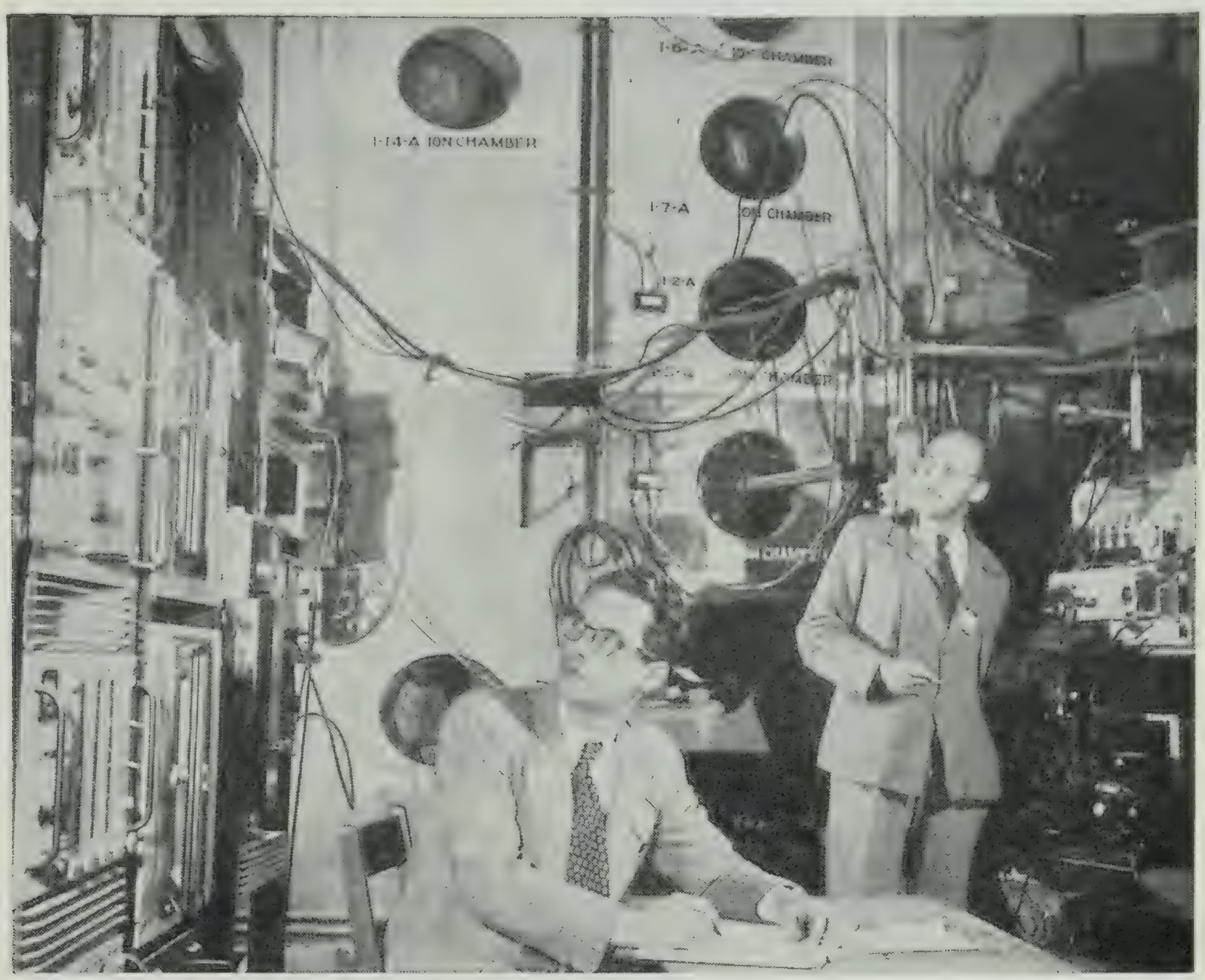
Great progress has been made in putting the atom to work to cook



This drawing shows a free neutron splitting the nucleus of an atom to release atomic energy and set free more neutrons which split other atoms. This is known as a chain reaction, and results in the release of a very large amount of atomic energy. The discovery of a way of splitting the nucleus of the uranium atom was one of the greatest scientific achievements of modern times. Already atomic energy is performing important work in producing electricity and in operating ships and submarines. In the future atomic energy will serve mankind in other ways.



A large atomic energy reactor at Chalk River, Ontario. Its size can be estimated by comparison with the height of the men in the picture. The cylindrical wall of the reactor is made of concrete, about ten feet thick, to prevent the escape of radiant energy. Within the reactor, atoms of uranium are split in two. When each uranium atom nucleus is split, a very large amount of atomic or nuclear energy is set free. (National Film Board photo)

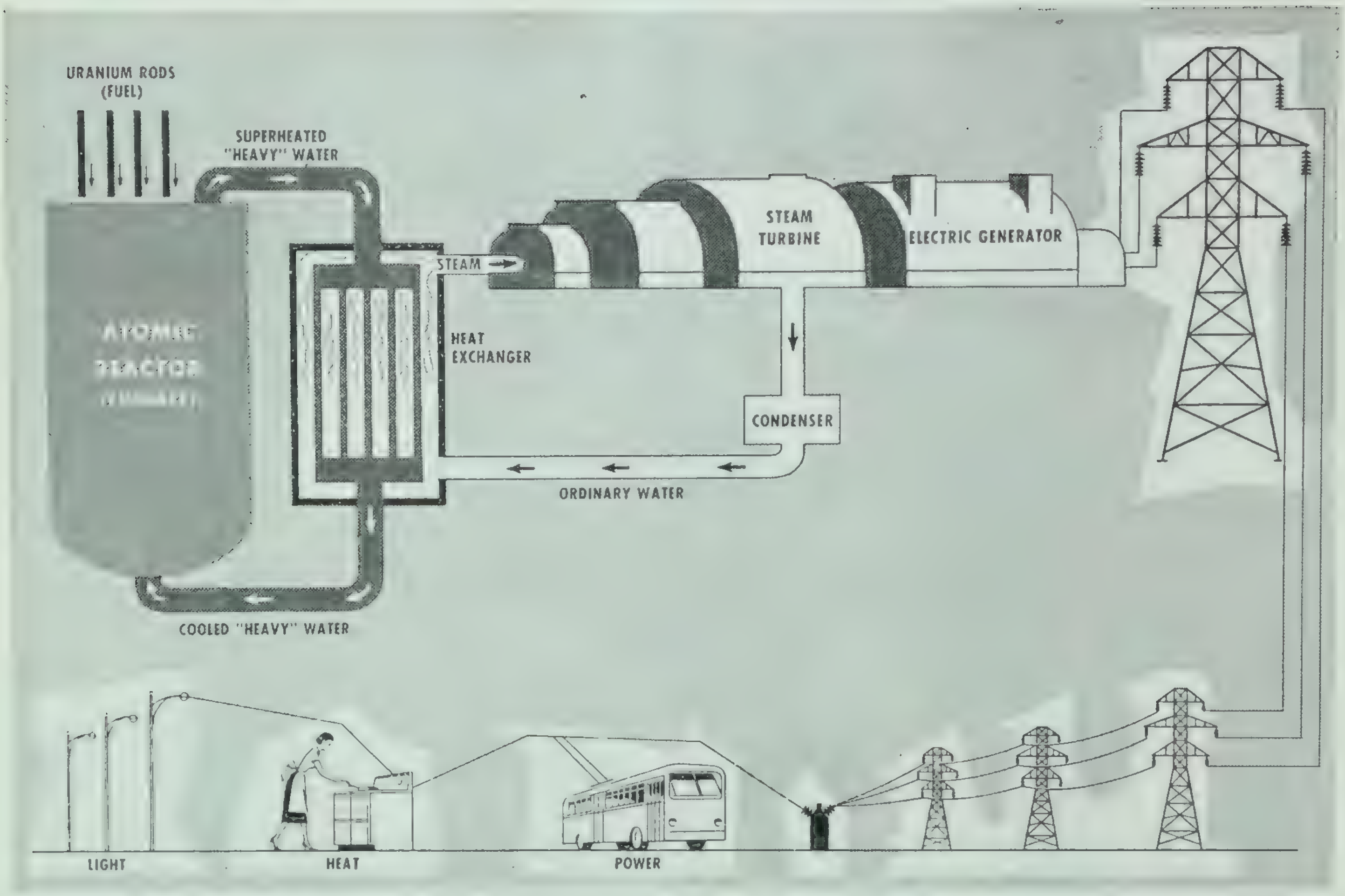


These scientists, who are performing experiments to find peaceful uses of atomic energy, are called nuclear physicists. (National Film Board photo)

meals, light lamps, and run machines. *Atomic power plants* are already in use in Great Britain. The electricity produced in these plants is used to supplement that produced from coal and other sources. In areas of the world where there are no natural sources of power, such as coal, oil, and waterfalls, atomic power appears to be a most promising possibility. Studying the diagram on page 212 will help you learn more about how atomic energy is used to produce electricity for domestic light, heat, and power. The heat generated by the release of atomic energy is used to generate steam which operates steam turbines to produce electricity.

Producing electricity from solar energy

Scientists have estimated that in two days the earth receives in sunlight more energy than is stored in all our known reserves of fuels. If this energy could be harnessed, what a tremendous source of power it would



An atomic electric-power plant. Heat, generated by a fuel source of uranium rods in the atomic reactor, or furnace, superheats "heavy" water which is piped through a heat exchanger. In the heat exchanger, heat from the "heavy" water turns ordinary water into steam. This steam operates a steam turbine, which in turn operates an electric generator and produces electricity that can be used for heat, light, and power. (Canadian General Electric photo)

be! The idea of harnessing the sun's energy has challenged scientists for a long time. In recent years, definite progress has been made in finding ways and means of capturing the sun's energy, or *solar energy* as it is often called, and using it to help us with our work. Already scientists are using solar energy to heat houses, cook meals, pump water, and generate electricity.

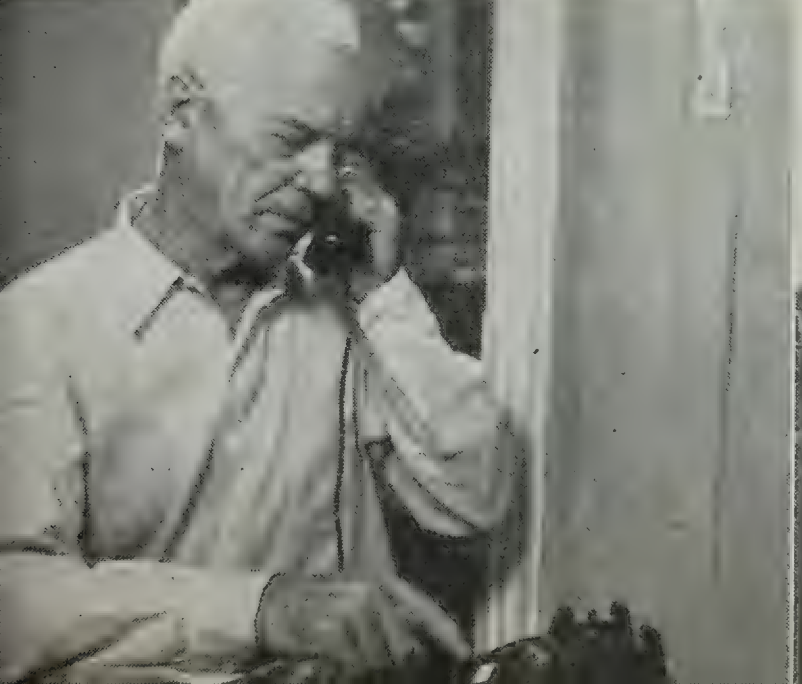
Scientists in the employ of The Bell Telephone Laboratories have invented a *solar battery* that is able to convert the energy of sunlight directly into electricity. The battery consists of a tray of black disks, each the size of a twenty-five-cent piece (see lower-right picture, page 213). The disks contain a substance that changes the sun's energy into electric energy. This source of energy is being successfully used on some telephone lines in rural areas. Part of the electricity produced during the day is stored in ordinary storage batteries to operate the telephone system at night. Further improvements in the solar battery will likely be made in the near future. From time to time you will probably hear about further progress in producing electricity from solar energy.

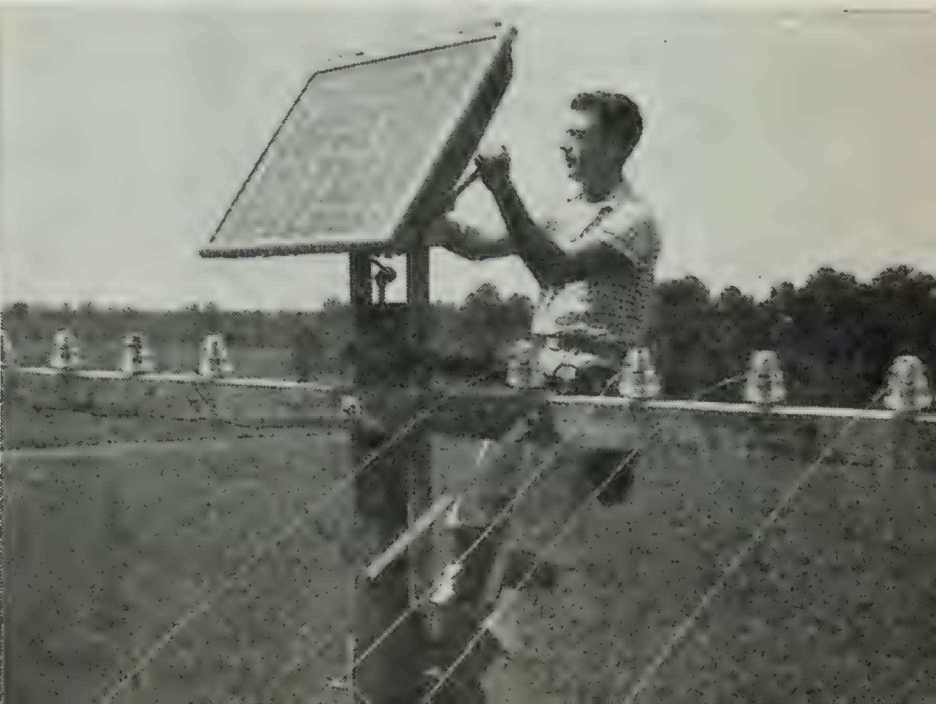
A pocket-size solar-powered radio, weighing only 10 ounces. It will operate continuously in daylight and will run 500 hours in darkness without recharging. (General Electric Company photo) →

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. Where are some of the larger hydro-electric power plants in Canada located?
2. In a hydro-electric plant, what is the purpose of each of the following: penstock, water turbine, electric generator?
3. Explain how the energy of running water is changed into electric energy in these power plants.
4. In a steam generating power plant in which the fuel used is coal, show that the electric energy generated came originally from the sun.
5. What is the source of atomic energy?
6. Explain how atomic energy is used in atomic power plants to produce electricity.
7. Why are atomic electric power plants likely to be located in areas where coal, oil, and waterfalls are scarce?
8. What is solar energy?
9. Describe a solar battery and explain how it can be used as a source of electricity.

The man on the left is using a telephone that is powered by a solar battery such as the one shown on the right. (Bell Telephone Laboratories photos)





ELECTRICITY IN THE HOME

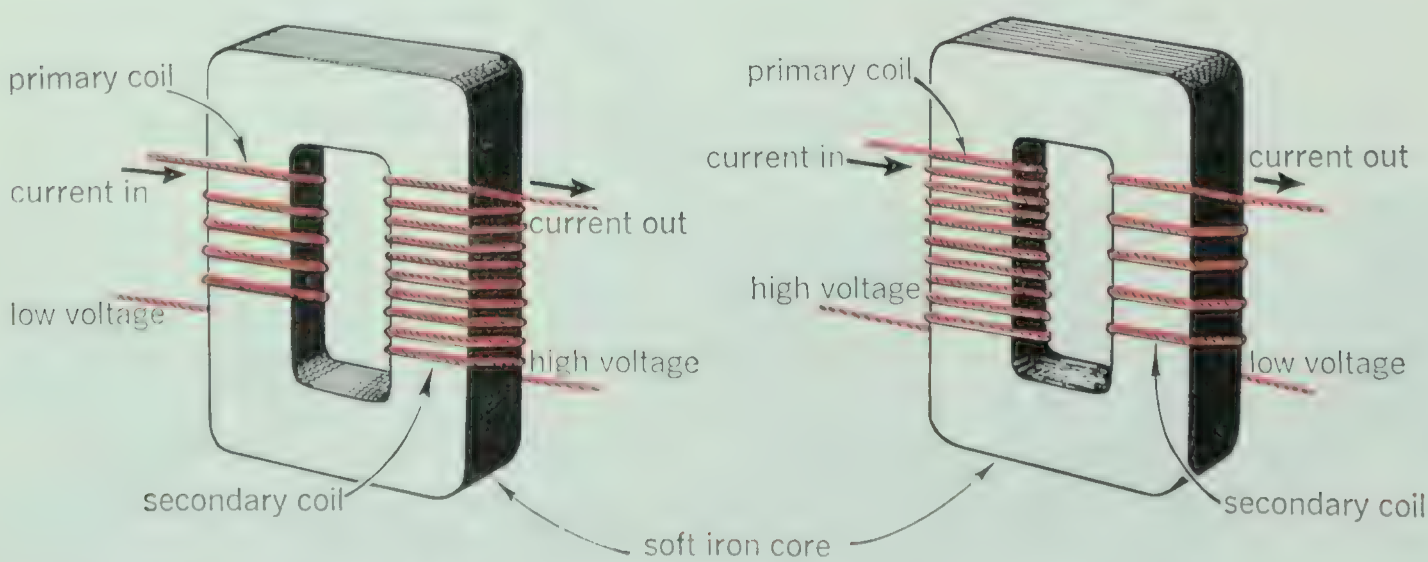
It usually happens that a hydroelectric (or other power plant) is many miles from the homes, factories, and other buildings where the electric power is needed. Therefore, many steps are required to make the energy of the rivers available in the home. The electricity has to be transmitted over long-distance power lines from the electric generators to the home. The longer the wires, the greater the resistance offered to the flow of the electrons. In order to overcome this resistance, the electrical pressure, or voltage, is increased; the longer the wires, the higher the voltage required to force the current through them. The increase in voltage is accomplished by means of a *transformer.*

Transformers

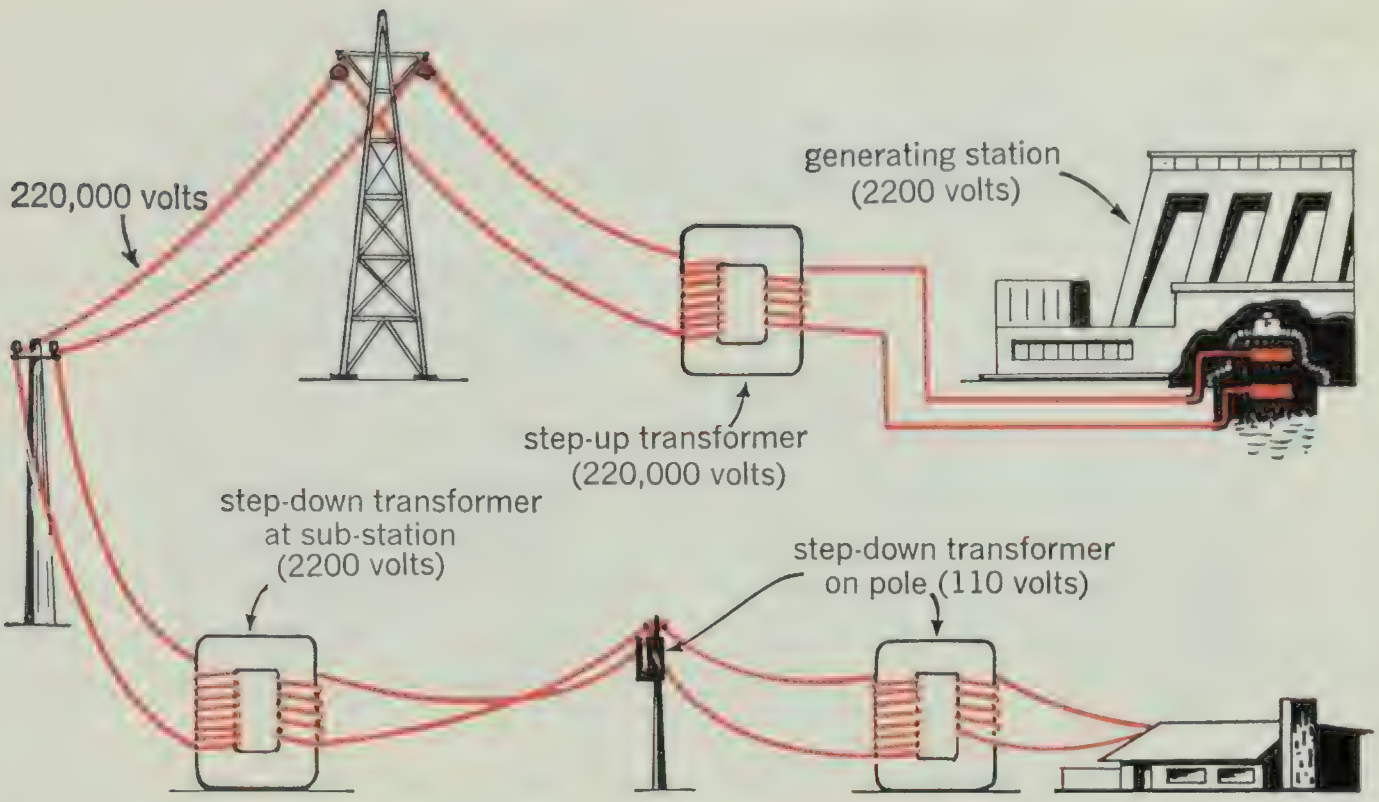
A transformer is a device used to change the voltage in power lines. If the voltage is to be increased, a *step-up transformer* is used. If the voltage is to be reduced, a *step-down transformer* is employed. (See diagram on this page and on page 215.)

A transformer consists of two coils of wire on the same core of iron or special alloy. The coil that is connected with the source of electricity (electric generator) is the *primary* coil; the other is the *secondary.* (See diagram on this page). When an alternating current passes through the primary coil, an alternating current is induced in the secondary coil circuit.

Let us assume that there are 50 turns of wire in the primary coil and 5000 in the secondary; the voltage in the secondary circuit will be 5000 divided by 50, or 100 times as great as the voltage in the primary circuit. If the voltage in the primary circuit is 200, the voltage in the secondary



Transformers. On the left is a step-up transformer. Why is it so called? On the right is a step-down transformer. Explain how these two types of transformers assist in transmitting electric power from the power plant to the home.



This drawing shows how electricity travels from the generating station to the home. What happens at the step-up transformer and at the two step-down transformers? At the step-up transformer, why is it necessary to increase the voltage for transmission through the power lines?

circuit would be 100 × 200 volts = 20,000 volts. This, then, is a step-up transformer.

Electric power can be calculated by multiplying the voltage by the amperage. Watts (power) = volts (pressure) × amperes (rate of flow).

Neglecting the loss of energy due to heat, we may say that the electric power in the primary circuit of a transformer equals the electric power in the secondary circuit. Hence, if the voltage is stepped up, the amperage is lowered; also, if the voltage is stepped down, the amperage is raised. This is in keeping with the statement that watts = volts × amperes.

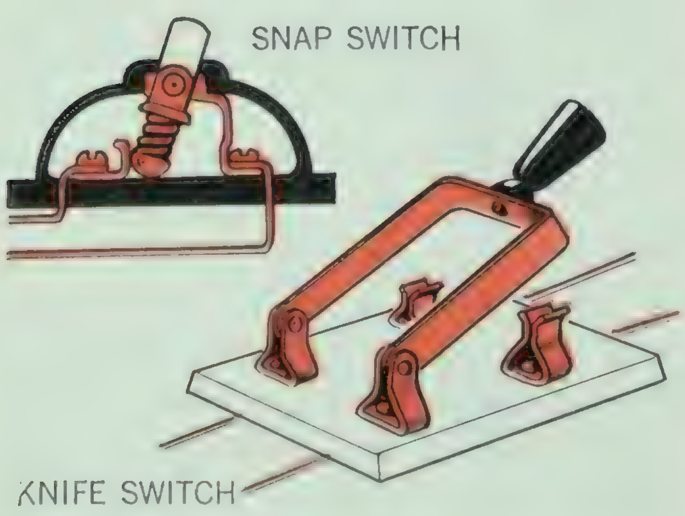
For long distance transmission of electric energy, the voltage may be stepped up to 220,000 volts or more. You will have seen the high voltage transmission lines that lead from the generating station to the city.

At a sub-station in the city the voltage is reduced to about 2200 volts by means of a step-down transformer in which the secondary coil has *fewer* turns than the primary. Finally, by means of another step-down transformer, often located near the top of a power-line pole near the home, the voltage is stepped down to 110 volts, which is the voltage usually present in the wires leading into the home. Although the voltage used in high tension power lines varies greatly, the general method of transmitting electric energy with as little wastage of energy as possible is based on the same scientific principle in each case.

Controlling the flow of electricity by switches

Since it is not desirable to have a current flowing in a circuit at all times, it is necessary to have some means of controlling the flow. Such a means is provided by the *electric switch,* which is available in a variety of simple and convenient forms. The types that are chiefly used in homes are the *knife,* the *snap,* and the *plug.* (See diagram on this page.) If your home is lighted by electricity, you should be able to find all three of these in it. Look for them.

The heavy-duty knife switch in your home is used to disconnect the entire wiring system from the power line. Disconnecting the wiring is necessary when repairs or alterations are being made to the system; it is also a wise precaution when the house is to be left unoccupied for a considerable period, as it reduces the fire hazard.



Explain how each of the above instruments is used to control the flow of electricity in the home.

The snap type of switch is the one used in homes for individual lights. Each switch controls the light only in that part of the circuit to which it belongs.

The plug switch is used with movable electrical appliances, such as irons, curlers, floor and table lamps, vacuum cleaners, and radios. This type of switch, in addition to controlling current, affords a convenient means of disconnecting the appliance from the circuit so that the appliance can be removed when not in use.

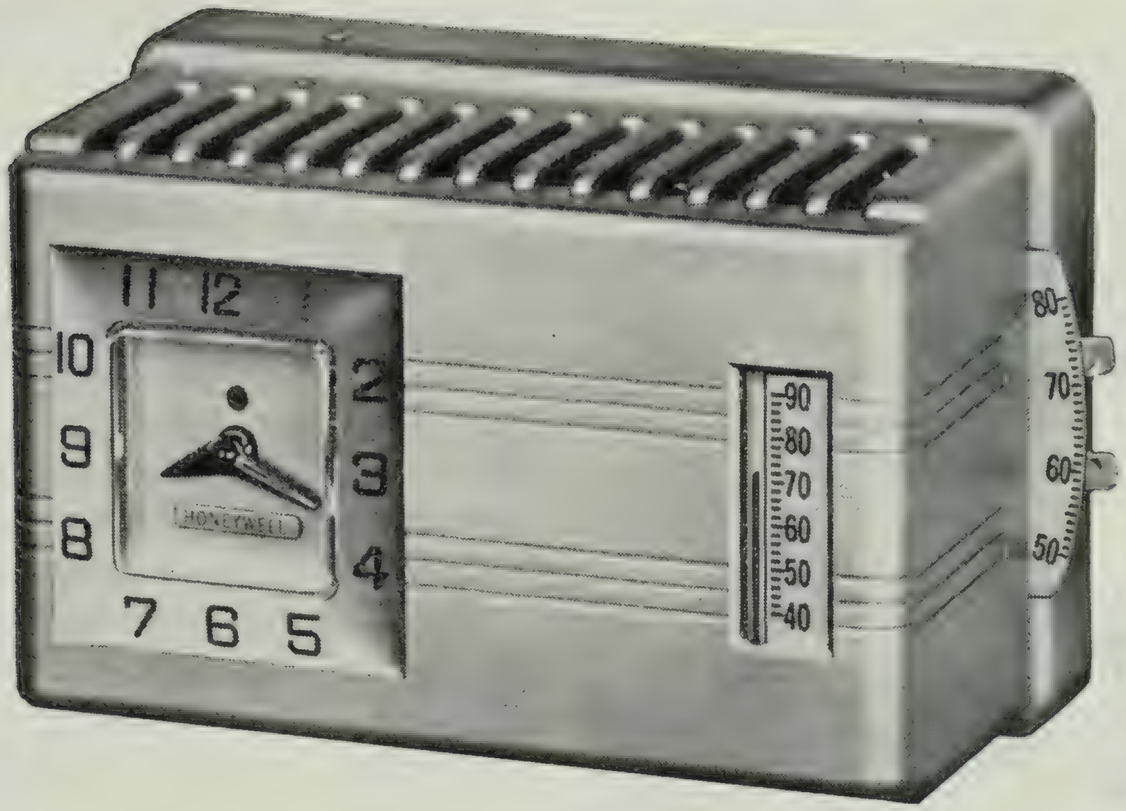
SOMETHING TO DO

1. Look around your home to find the different types of switches that are used to control the flow of electricity.
2. Examine these different types of switches to see how they are constructed and how they operate.

There are many other forms of switches. One of them, the *circuit-breaker,* is operated by electromagnets. These are to be found in power plants and street-railway cars. Another form of switch is the electric *thermostat,* which is used in modern homes and other buildings to regulate temperature.

How fuses protect our homes

If you examine the main switch box in your home, you will find a number of fuses. Fuses are the "safety valves" placed in electric circuits in buildings and in electrical equipment to prevent damage by fire and other causes. The



This thermostat regulates the furnace, keeping the house at one temperature during the day, and at a cooler temperature during the night. What are two advantages of such a thermostat? Why is the clock an essential part of this thermostat? Study the dial on the right end. At what temperature is it set for daytime? For night? Which of the two controls, day or night, is now operating? How do you know? (Minneapolis-Honeywell Regulator Co. photo)

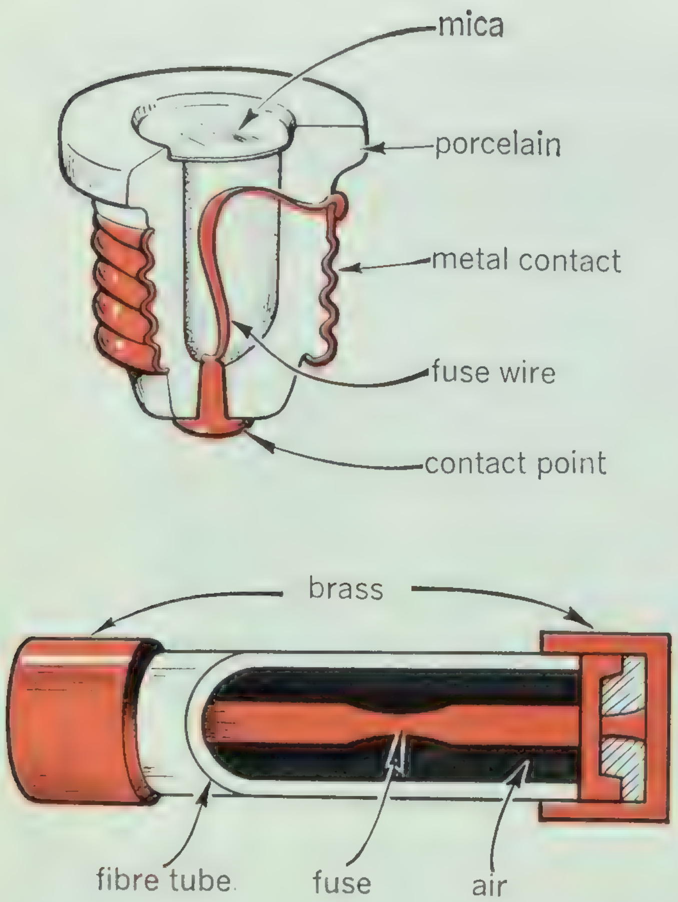
fuse is so arranged that the electric current must pass through a ribbon of *fuse wire,* which is usually a mixture of lead and tin. The fuse wire has a higher resistance (so that it heats more quickly) and a lower melting point (so that it melts more readily) than the wire in the rest of the circuit. Should the current become excessive by overloading, short-circuiting, or other cause, the fuse wire melts, or "blows out." This breaks the circuit before damage caused by overheating results in any part of it.

There are several types of fuses. The most commonly used type is the *plug fuse,* which is designed to screw into any standard socket and which can be obtained in a number of sizes.

Another form of fuse in common use in the main switch block of houses and in the electric stove circuit is that known as the *cartridge fuse.* Such fuses are held in the circuit by means of spring clips and are obtainable in a range of sizes.

Safety in the electric circuits in homes and other buildings may now be provided by the installation of automatic electric *circuit breakers,* which break the circuit immediately it becomes overloaded.

NOTE. – In selecting a fuse or circuit breaker you must always be careful to choose one that has the same current-carrying capacity as the line in which it is to be used. If you use a fuse with too high amperage for



A plug fuse (above) and a cartridge fuse (below). What purpose is served by the fuse wire?

the circuit, you have little or no protection. If you use a fuse with too low amperage, the fuse will "blow" every time you close the circuit.

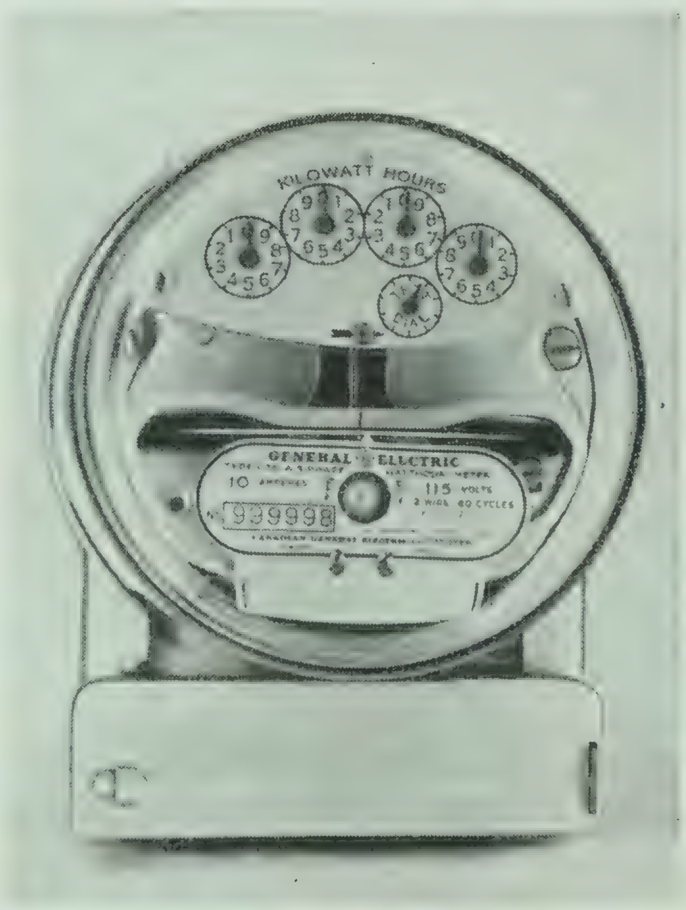
SOMETHING TO DO

1. Obtain a fuse plug, and examine it carefully. Find all the parts that are indicated in the diagram above.
2. Look around your home to find where cartridge fuses are in use. Examine one of them to find the essential parts. What is its amperage rating? Why is it important to use a fuse of correct amperage for the circuit in which it is inserted?

How is electricity measured and sold?

Stamped on many electrical appliances you will find the words *volt* and *ampere*. You also heard of these terms when you were learning about transformers.

The power of an electric current to produce heat and light or to turn a motor depends upon its pressure (volts) and upon its strength, or rate of flow (amperes). The unit for measuring the power of a current is the *watt*. To find the number of watts an electric iron is using per hour, multiply the number of amperes the iron requires by the voltage of the current (usually 110 volts). For example, an iron that requires 10 amperes will use 10 (amperes) $\times$ 110 (volts),



An electric meter. Compare the meter shown here with the one in your home. The meter is used to measure the number of kilowatt hours of electric energy that pass through the electric wires into the house. (Canadian General Electric photo)

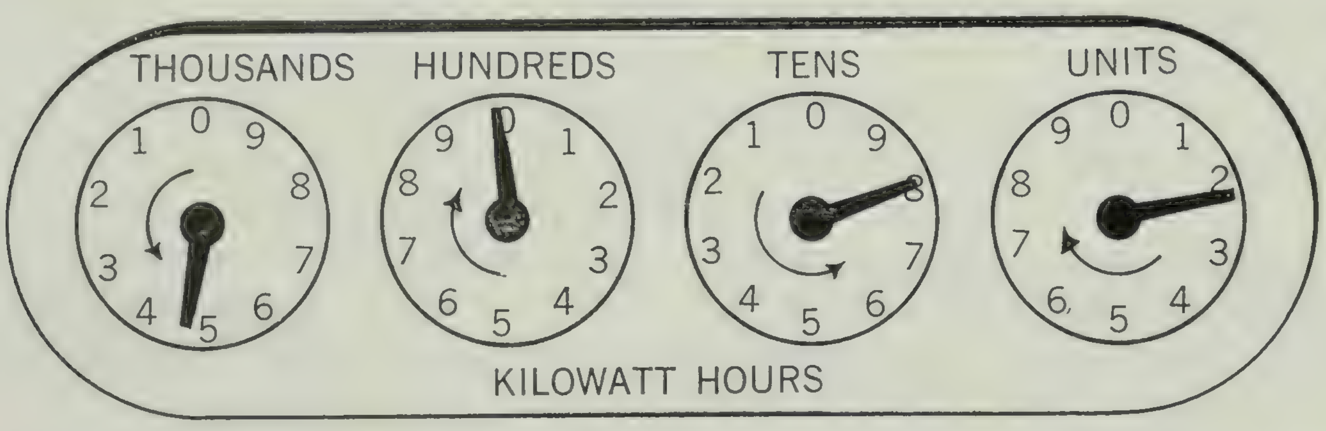
which equals 1100 watts. Watts = Amperes × Volts.

If you examine an electric light bill, you will see that a charge is made for a number of kilowatt hours of electricity. Large quantities of electrical power are measured in kilowatts (a kilowatt = 1000 watts). If a kilowatt of electrical power is used for one hour, a charge will be made for 1 kilowatt hour, or 1 kw.h. of electric energy. To find the cost of operating the electric iron previously mentioned, divide 1100 watts by 1000; the result is 1.1 kilowatts. Suppose the cost is 4 cents per kw.h. Then, 1.1 kilowatts of electrical power used for one hour would cost 1.1 × 4 = 4.4 cents.

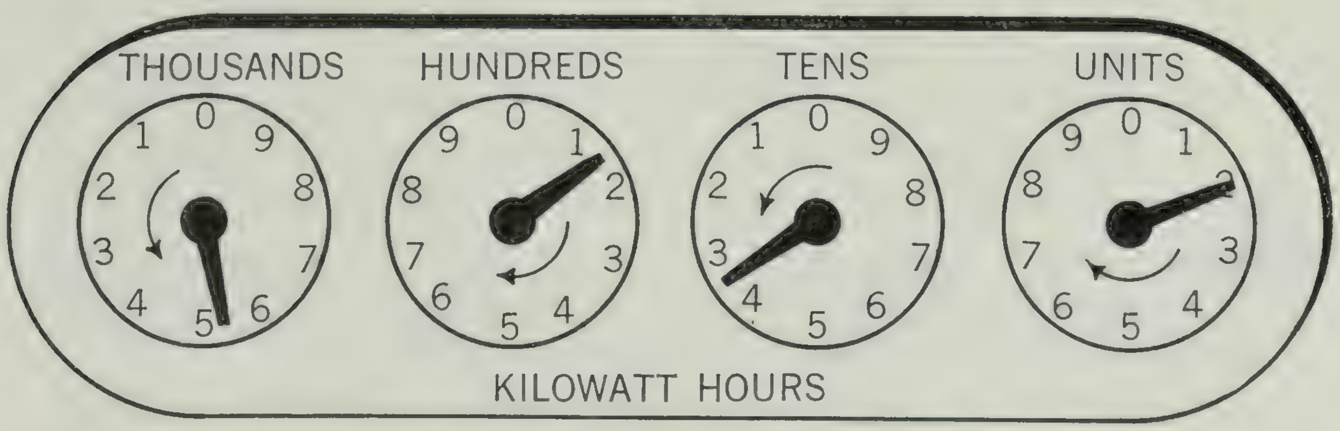
The larger electric light bulbs are usually rated in watts of power that they require. What would it cost to use a 60-watt bulb for 3 hours a day for 30 days in a town where electrical power cost 4 cents per kilowatt hour?

Cost = 60(watts)×3(hours)
×30(days)÷1000
= 5.4 kw.h., at 4 cents per kw.h.
= 21.6 cents.

Work this example out for yourself to check and to see how the cost of light and electrical power is calculated.



The reading of this meter is now 4982. The thousands hand is between 4 and 5, the hundreds hand between 9 and 10, the tens hand between 8 and 9, and the units hand between 2 and 3. Notice carefully that the hands do not all turn in the same direction.



Dials of the meter a month later. What is the reading? How many kilowatt hours of electrical energy have been used since the meter stood at the reading shown in the upper diagram?

SOMETHING TO DO

1. Examine the kilowatt-hour meter used to measure the electrical power consumed in your home. It is a slow-running electric motor that turns pointers on several dials. Do not disturb the meter in any way — it is possible to examine it without doing this. If the pointers on the various dials are between figures, the lower one gives the correct reading. For example, if the pointer is between 3 and 4, the reading is 3.

2. Read the meters shown on page 219 and calculate the light bill for the month.

3. Draw four small circles on the blackboard and mark figures from 1 to 0 in each circle to represent the dials of a kilowatt-hour meter. Write a reading, such as 4625, on a sheet of paper. Draw pointers in your circles to represent the reading. Ask a classmate to make a reading of your dials. Check his reading with the one you have written on the paper.

4. Find the rate per kilowatt hour that is charged for electrical power in your locality for (1) light, and (2) cooking purposes.

5. Examine various electrical appliances, such as irons, toasters, stoves, radios, etc., to find the label indicating the number of volts and amperes (or watts) required to operate them.

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. By means of a simple diagram show the structure of a transformer.

2. When electric power is to be transmitted over long-distance power lines, a step-up transformer is used to increase the voltage. What is the advantage of this?

3. Why is a step-down transformer usually to be found near a house in which electric power is used?

4. Describe a screw fuse plug. How do fuse plugs safeguard buildings from fire?

5. Give two reasons why fuses sometimes "blow." What purpose is served by the fuse wire?

6. Why is it a dangerous practice to replace a burned-out fuse with a penny that completes the electric circuit?

7. What are the uses of the electrical switches in your home?

8. What electrical unit is used to measure each of the following: (1) current strength, or rate of flow, (2) electric pressure, and (3) electric power?

9. Knowing the pressure in *volts* and the current strength in *amperes*, how can you find the power in *watts*?

10. How much electrical energy is used in lighting a 40-watt lamp for 2 hours a day for a 30-day month? What would it cost at 5 cents per kw.h.?

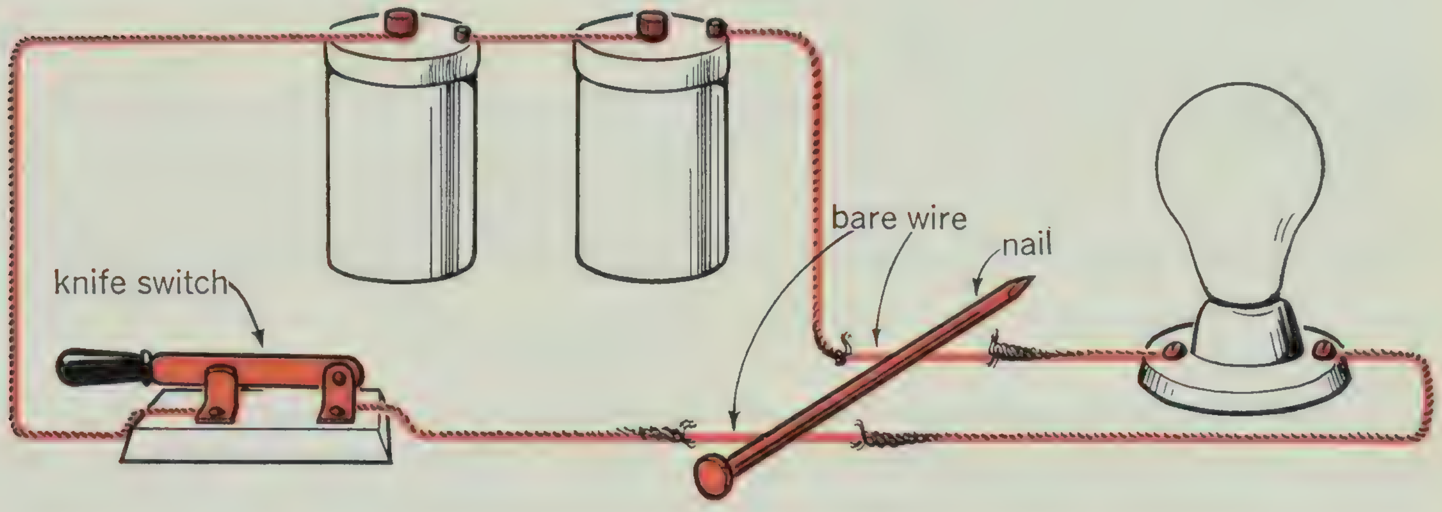
11. If the pressure of an electric current is 110 volts, and an electric toaster uses a current of 5 amperes, how many kilowatts of electrical energy are required to operate the toaster for two hours? What would it cost at 6 cents per kw.h.?

HEAT FROM ELECTRICITY

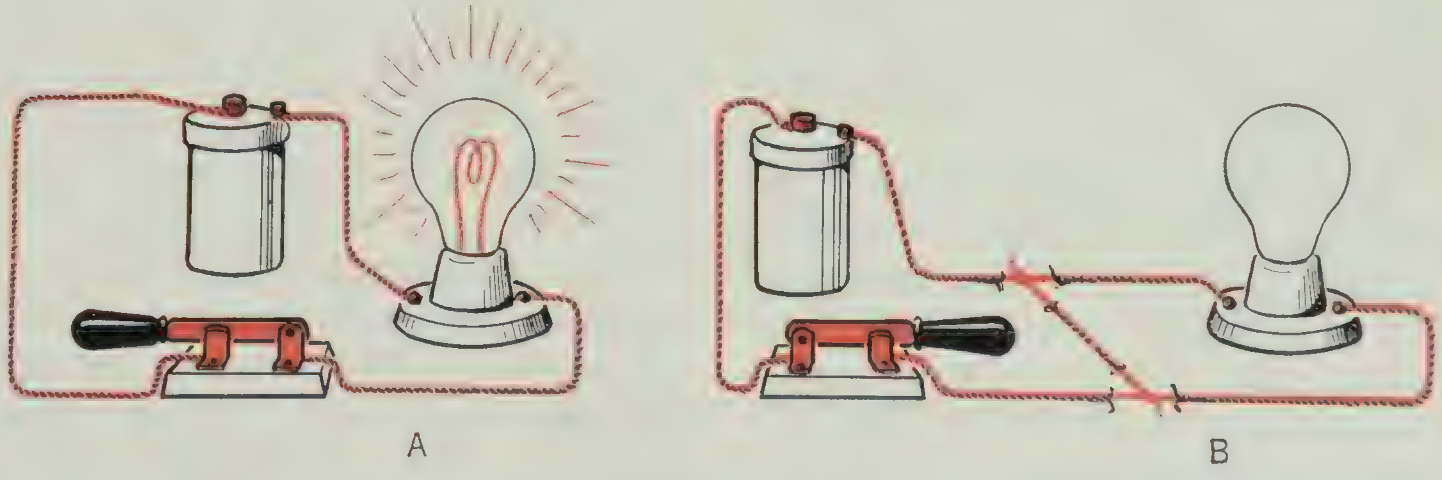
Sometimes the electric cord that is used with a toaster, iron, or stand lamp becomes frayed to the point where all the insulation is worn off a part of the cord, thus exposing the bare copper wires to view. When this condition develops, it often happens that the two bare wires in the cord touch each other. If they do, a *short circuit* results.

What are short circuits?

Copper wire, as you know, is an excellent conductor. For this reason it



An experiment to illustrate a short circuit. How do you know that the nail lying across the bare wires caused a short circuit?



An alternative experiment. In B part of the experiment another wire is placed in the circuit as shown by the dotted line. Why does the bulb light up in A but not in B?

offers very little resistance to the flow of an electric current. Thus, when the two wires touch, there is a great rush of electricity around this new and easy path. Instead of having to travel through the resistance wires of the toaster, iron, or electric light, the current takes the easy way, or short circuit. The rush of electricity, often accompanied by sparking, heats the copper wire. However, if there is a fuse in the circuit, the fuse "blows" before any damage can be done. In so doing it breaks the circuit and prevents serious over-heating that might otherwise have caused a fire.

In what other ways may a short circuit be caused? What is the danger of a condition where old and worn wiring is used to carry electric currents in a home or where bare electric wires are exposed?

SOMETHING TO DO

1. How may a short circuit be produced? To find the answer to this question, make the following test:

Using copper wire, connect in a circuit two dry cells, a flashlight bulb, and a switch, as shown in the diagram on page 221. By closing the switch, test to find if the circuit is complete, then open the switch.

Remove the insulation from the copper wire in two places, as is illustrated in the diagram on page 221. With the switch still *open*, lay a nail across the bared wires in the circuit.

Now close the switch. What happens? What evidence was there to indicate that the nail lying across the bared wires had resulted in a "short"?

2. Check the electric cords used in your home to discover if the insulation is badly worn on any of them. Worn cords should be replaced or repaired.

NOTE. — Be sure that the cords are disconnected from the electric circuit before you start to examine them.

Heating effects of an electric current

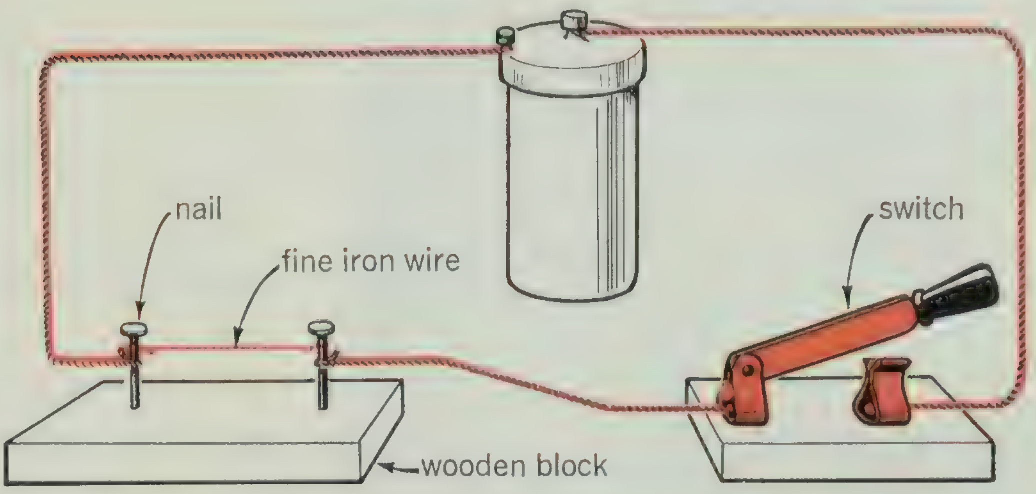
The day that scientists discovered that an electric current can be used to produce heat and light was a happy one for us. You might pause to consider for a moment what this discovery has meant to your comfort and happiness.

Electricity, as you know, is a form of energy. Fortunately for us, scientists have learned how to change electrical energy into other forms such as heat, light, and mechanical energy.

SOMETHING TO DO

Problem. — Can electrical energy be changed into heat? Assemble the apparatus and materials as shown in the diagram on page 223.

Method. — (1) Stretch a fine *iron* wire between two nails or screws in a board. Using copper wire, connect the dry cell, knife switch, and fine iron wire in a circuit, as shown on page 223. (2) Press down the lever of the knife switch so as to close the circuit for a few seconds, then raise it again. What happens to the fine iron wire? Did the copper wire become hot? (3) Next use two dry cells connected in parallel to provide a stronger current. (See diagram on page 172.) Close the circuit by closing the knife switch. What do you observe?



An experiment to illustrate the heating effects of an electric current.

Compare your observations this time with what you observed in step 2. Does increasing the rate of flow of electricity increase the heating effect of the current? Account for the results of your experiment.

When an electric current passes through wire that offers considerable *resistance* to it, the wire gets hot; the finer the wire, the hotter it becomes. Also, the greater the flow of electricity, the greater the heating effect.

Copper wire is a good conductor of electricity. In other words, copper offers little resistance to the flow of electrons through it. Tungsten offers greater resistance than copper, and iron offers much higher resistance than tungsten. Conductors, such as iron and tungsten, that offer considerable resistance to the flow of an electric current through them, become hot. Sometimes they become red hot or even white hot. The resistance offered by the conductor causes electrical energy to change into heat energy.

Some alloys or mixtures of metals offer very great resistance to an electric current. For example, *nichrome,* a mixture of nickel and chromium, has a resistance 60 times as great as the resistance of copper. It does not melt or burn even when red hot. For these reasons nichrome is widely used in elements in electric heating appliances.

Heating appliances

Most modern homes contain many conveniences in which electrical energy is changed into heat. Some of these handy and useful inventions are: electric irons, toasters, coffee makers, waffle irons, electric frying pans, electric stoves, hot plates, water heaters, blankets, heating pads, and many others. Another useful electrical heating device is the block heater used in automobiles in winter.

In all of these electrical appliances a resistance wire, or *element,* is used in the production of heat. The element used must meet certain requirements. It must have a high resistance to an electric current, must not melt when it gets very hot, and must not burn when heated.

In an electric stove, electric energy is changed into heat energy. How is this accomplished? Note the electric meat thermometer inserted in the turkey which can be set to control automatically the degree of roasting. (Canadian General Electric photo)

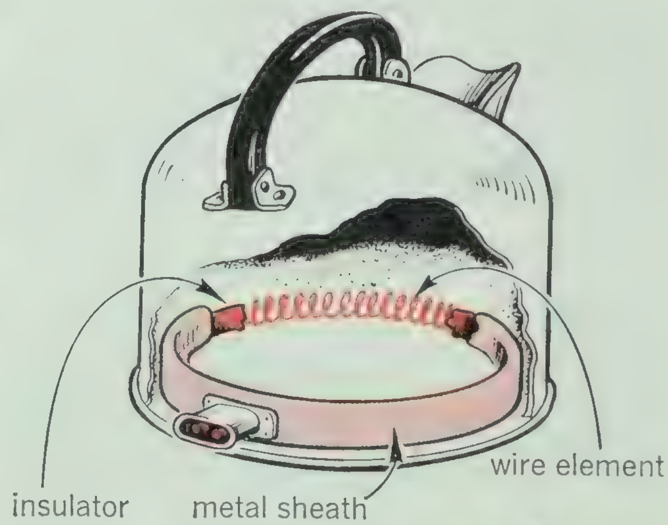
SOMETHING TO DO

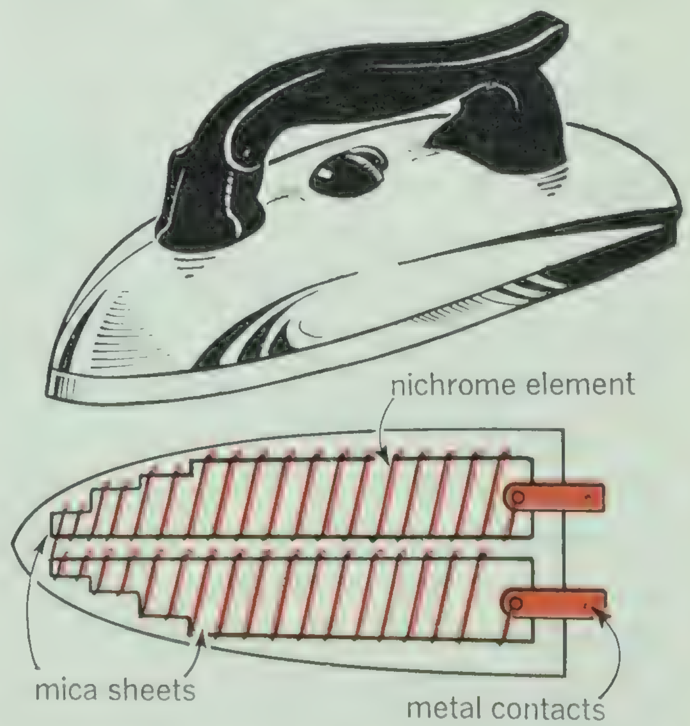
Dismantle a discarded electric iron or an electric toaster to find the heating element. Is it wound on mica? Is it sandwiched between mica strips?

Usually fine wires of fairly high resistance are used for heating elements. Often the element consists of a *coil of bare wire*, as seen in some toasters. Sometimes it is a flat *metal ribbon*. In electric stoves, block heaters, and water heaters, the heating element is a *solid rod*. Regardless of size or shape, heating elements are made of materials that can be heated to a very high temperature without melting or burning. Often these elements are enclosed in a non-conductor such as porcelain, or in some other insulating material. Possibly the most common material found in heating elements is the alloy nichrome.

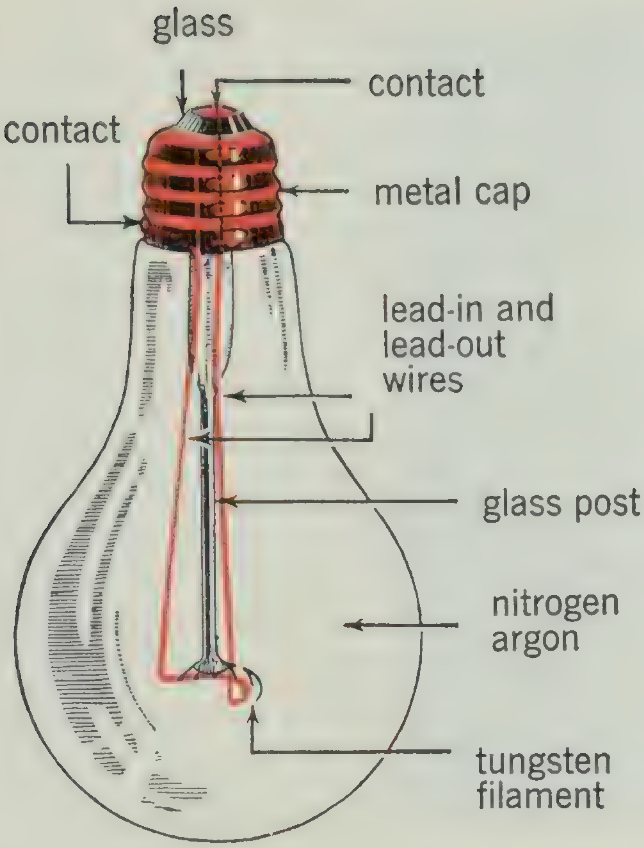
The story of light

Have you ever stopped to consider how man's use of light has increased over the past 500,000 years? Long,

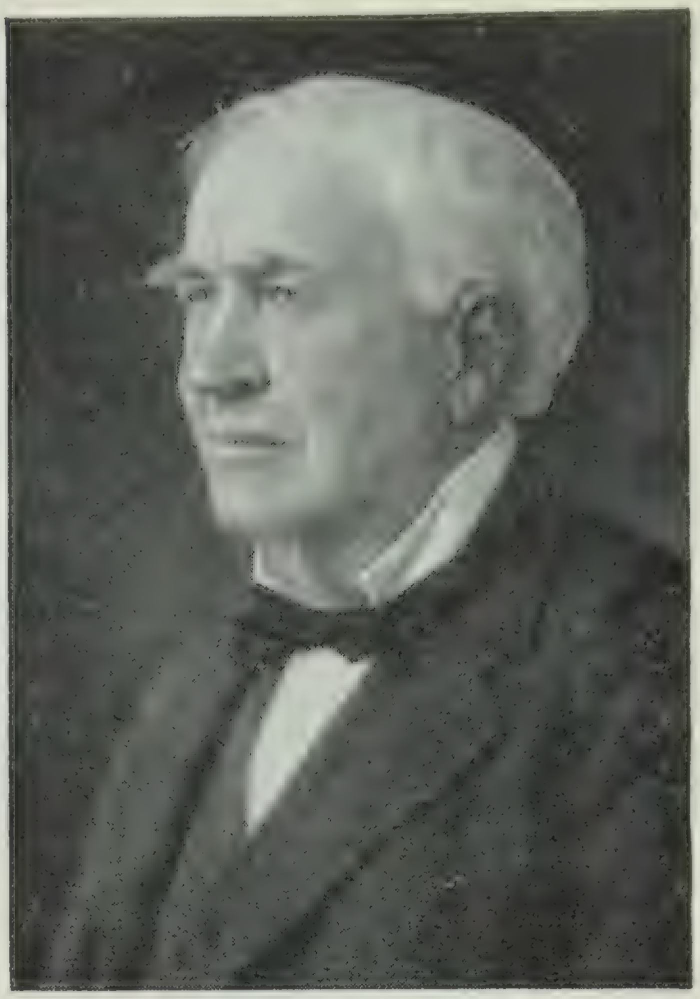




The electric kettle and the electric iron are two of the many modern appliances that change electrical energy into heat energy. How is the electrical element insulated in each appliance?



Carefully break and remove the glass of a burned-out electric light bulb. Find the parts shown in this illustration. Trace the path followed by the electric current. Tungsten is a poor conductor of electricity and as a result it becomes white hot when an electric current passes through it. This produces a bright light. Why is the air removed from the bulb and replaced by nitrogen and argon?



Thomas A. Edison performed thousands of experiments with electricity. One of his best-known inventions is the incandescent electric light lamp, commonly called the electric light. (General Electric Company photo)

long ago, man's only sources of light were the sun, the moon, and the stars.

Light from burning fuels

After man discovered how to make a fire, he was able to supply his dark cave with light from a blazing *open fire,* which, no doubt, provided his first artificial light. Burning sticks were used as portable sources of light. Soon man learned to dip the end of a burning stick into pine pitch and set fire to the pitch to make a flaming *torch*.

The early Greeks and Romans learned to use *oil lamps* consisting of shallow dishes containing an oil that could be burned to produce light. Unfortunately, the burning of the oil usually resulted in a very unpleasant odor. These lamps were followed by stone and pottery *wick lamps* in which vegetable oil or melted animal fat were burned. *Candles* made of tallow or sheep fat came into common use about the same time. By the year 1820 it was discovered that *coal gas* could be used as a fuel for lighting.

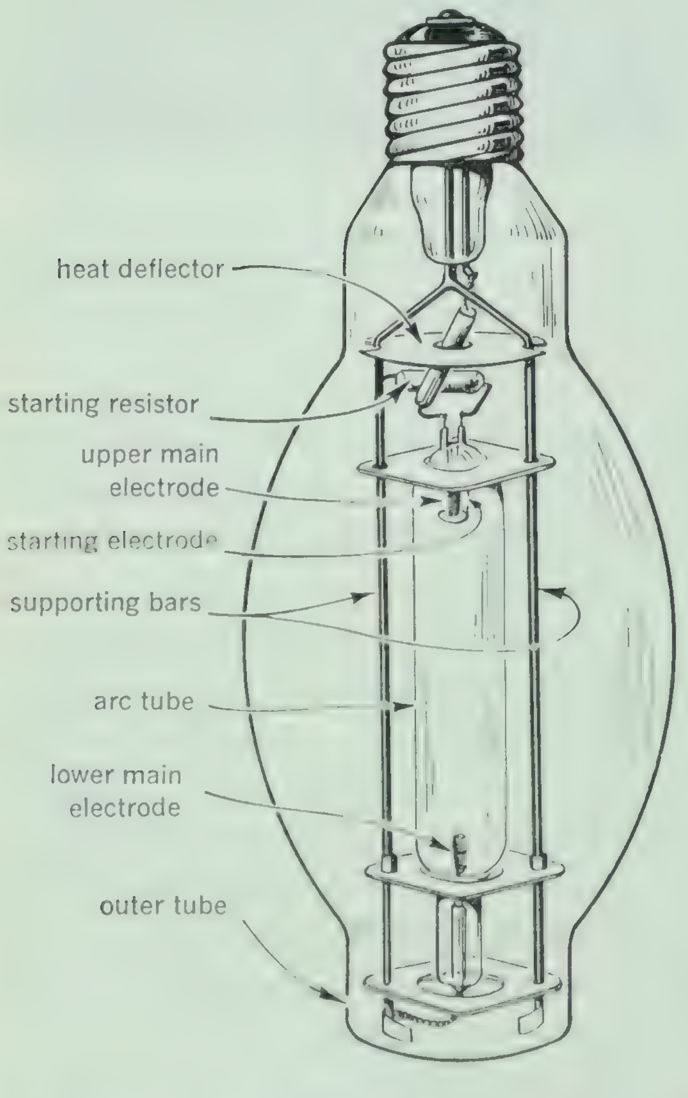
After man had learned how to distill petroleum to produce coal-oil or *kerosene,* the kerosene lamp was invented.

It replaced all other wick lamps. Kerosene lamps are still in use in some remote rural areas, but their use today is very limited.

All of the sources of artificial light mentioned so far are the result of *burning fuels*, namely, wood, pitch, oil, tallow, coal, gas, and kerosene.

Changing electric energy into light

After scientists learned how to generate electric energy, it was not long until they discovered how to use this energy for the benefit of mankind.



A mercury lamp. Find the parts that are labelled. If a mercury lamp is available, examine the visible parts.

They soon learned that when an electric current was passed through certain conductors, the conductors became hot; electric energy was changed into heat energy. Sometimes the conductor became white hot and gave off light.

Although an Englishman by the name of Joseph Swan was the first to achieve success in the production of an "electric lamp," it remained for Thomas A. Edison to produce, in 1879, the first practical and commercially successful *incandescent electric lamp*. In these early lamps a *carbon filament* was heated in a vacuum to a white heat, or *incandescence*, and it emitted a fairly bright light. Later, the metal tungsten displaced the carbon, chiefly because it could be heated to a higher temperature (1600° F.) before melting. The higher the operating temperature of the filament, the brighter and more efficient the light. The *vacuum bulb* was replaced by one filled with a mixture of two inactive gases, argon and nitrogen. A *gas-filled bulb* remains cleaner inside; also, as the evaporation of the tungsten is retarded by the gases, the tungsten can thus be heated to a higher temperature. Of what advantage is this?

Improvements are still being made in light bulbs. For example, your home or school may be lighted with fluorescent light bulbs. Another new type of bulb, known as the mercury lamp, makes very efficient use of electrical energy. One kind of mercury lamp is shown on this page. Watch for other types of mercury lamps.

An electric sewing machine is a great convenience in a home. It speeds up and lightens the work of the dressmaker. An electric motor operates the machine. (G. L. Hillyard photo)

Electricity improves living in many ways

Besides providing us with numerous heating devices and electric lights, electricity has made our work faster and easier in many ways. In most modern homes in our country you can find numerous examples of labor-saving devices that are operated by electricity. These machines have lightened and speeded-up the work of the home.

Some household labor-saving machines, such as electric floor polishers, sweepers, and washing machines, are operated by electric motors. An electric motor is designed to change electrical energy into energy of motion or mechanical energy. The electric motor in a floor polisher, for example, uses electrical energy to cause the rotation of the brush that polishes the waxed floor.

Electric mixers, washer-driers, knife sharpeners, electric saws, and hedge clippers are other labor-saving devices in and about the home that are operated by electricity.

In addition to labor-saving machines, most homes have other electrically-operated devices such as electric lights, stoves, record players, radios, telephones, electric clocks, and electric shavers, which, although they may not necessarily lighten our work, do add greatly to our comfort and enjoyment of life. Largely through the efforts of scientists and inventors, electricity has become man's most effiicient and versatile servant.

While electricity has many important uses in the home, it can also be a source of danger. Over-loaded circuits and frayed electric cords can lead to fire, which may result in serious property damage and even

loss of life. You must realize, therefore, that electricity can be dangerous if safety rules are ignored.

Electricity is also widely used outside the home. Some examples of these uses are: electric trolleys for transportation; power tools such as electric saws and power drills for construction work; and electrically operated machines in factories, stores, hospitals, on farms, and elsewhere in our environment that serve a great variety of purposes. What are some of these purposes?

SOMETHING TO DO

1. Make a list of electrically-operated labor-saving devices to be found in a modern home. Arrange them according to the location in the home where they are likely to be used. You might organize your lists under headings such as kitchen, dining room, bathroom, laundry, basement, elsewhere in the house.

2. Make another list of electrically-operated labor-saving machines that are used in your community. In preparing your list, think of machines used on modern farms and in repair shops, garages, stores, and factories.

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. Describe an experiment that you performed to find out whether electrical energy can be changed into heat.

2. Why is nichrome often used in electrical heating appliances such as stoves and electric irons?

3. Make a list of 5 or more heating appliances in the home in which electrical energy is changed into heat energy.

4. Electricity is used to operate electric motors, which in turn operate numerous labor-saving devices in our homes and elsewhere in our environment. List at least 10 such labor-saving devices.

5. For thousands of years man produced artificial light to serve his needs by burning fuels of various kinds. Make a list of these fuels.

6. (*a*) By means of a labelled diagram, show the construction of a modern incandescent electric lamp.

   (*b*) Explain how light is produced in this lamp.

7. What are the advantages in an "electric light" of: (1) using tungsten instead of carbon for the filament, (2) filling the bulb with nitrogen and argon instead of leaving it a vacuum?

8. What kinds of better light bulbs have been developed in recent years?

9. (*a*) What is a short circuit?

   (*b*) How may short circuits be caused?

   (*c*) Why are short circuits sometimes dangerous?

ELECTRICITY AIDS RAPID COMMUNICATION

In Chapter 4 you learned that electricity is used in the transmission of messages by telegraph and telephone. In this chapter you will learn more about the ways in which scientists have used electricity to provide us with rapid communication. The many scientists who have worked together to invent the telegraph, the telephone, the radio, and television have contributed greatly to our knowledge and understanding of the world around us. Many of the early discoveries about radio were made by Guglielmo Marconi.

The story of Marconi — the inventor of radio

Marconi was born in Italy in 1874. Even in his boyhood, he was greatly interested in experimenting with electricity. At twelve years of age, he was learning about the wonders of electromagnetic waves, which had recently been discovered by Hertz. He wondered if it might be possible to use these waves to send messages through space. Marconi dreamed that some day these magic waves, travelling with the speed of light, would carry messages from ship to ship and from one continent to another in a very small fraction of a second.

With this dream in mind, Marconi began to experiment. At opposite ends of his father's garden he set up tall poles. On the top of each, he attached strips of tin to serve as aerials. On the tin plate that was to be the sending aerial, he connected a coil by means of which electromagnetic waves (or radio waves) were sent out into space. The receiving aerial was grounded by running a wire from the tin plate down into the ground. For a receiving instrument, Marconi used a simple spark-gap apparatus connected with the receiving aerial. With this instrument, he succeeded in picking up the electric waves from the sending aerial and changing them into sound.

Encouraged by his first success, young Marconi continued to experiment. His ambition was to transmit messages by wireless telegraphy for hundreds of miles. By experimenting, he improved the instrument for receiving the wireless or radio waves, and found that higher aerials gave better results. With the improved apparatus, he was sending signals a distance of two miles or more by 1896. Marconi was greatly encouraged by this first use of the radio.

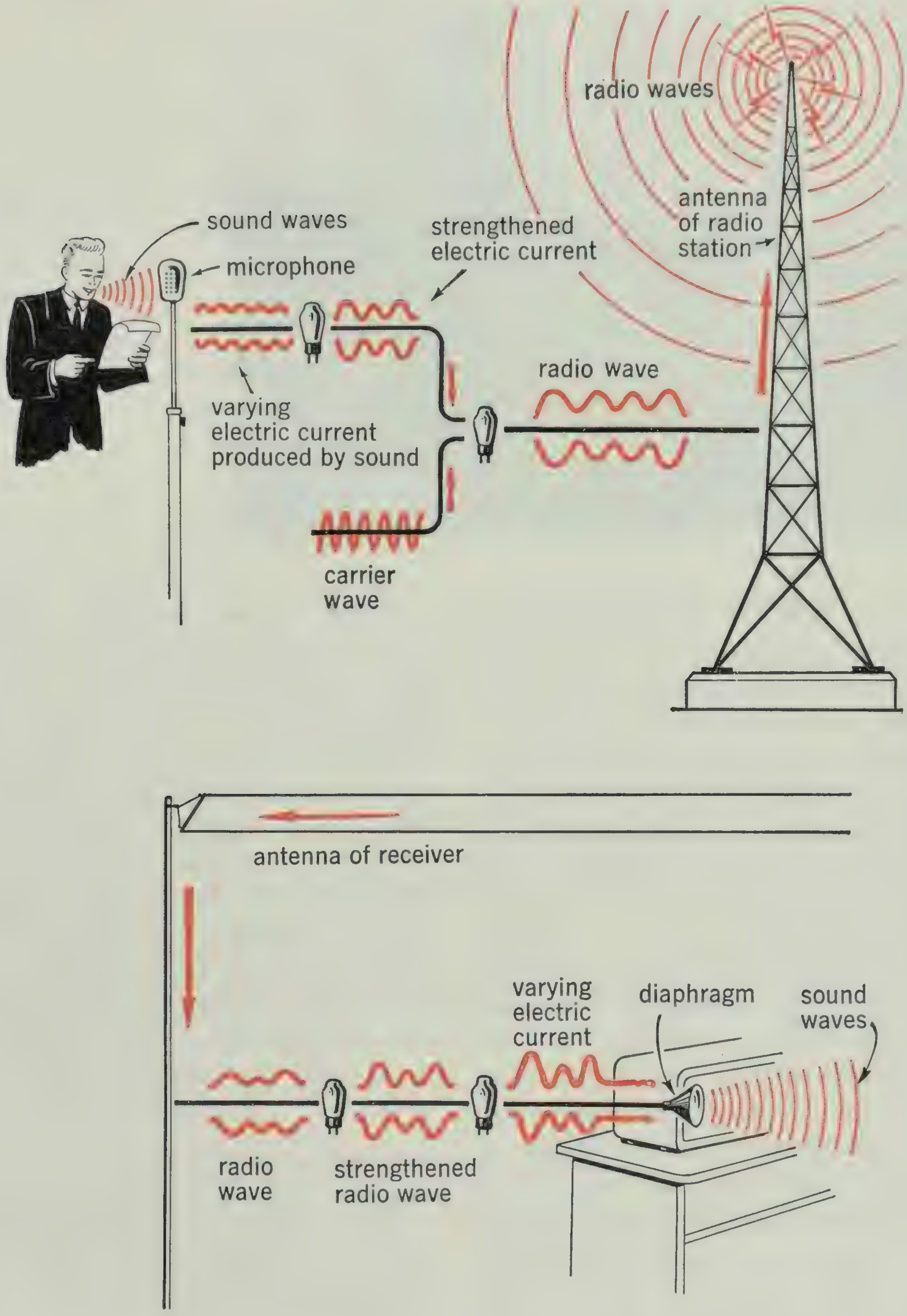
The following year, Marconi went to England, where he demonstrated his invention by sending wireless messages from the Isle of Wight to the mainland. His next demonstration showed how wireless sets could be used to send messages from ship to ship and from ship to shore. In 1899, he communicated successfully with a receiver on the other side of the English Channel. Great interest was aroused when movements of British warships in a sham battle were directed by wireless.

Marconi continued to experiment and to improve his instruments. On December 12, 1901, his fondest hopes were realized when he succeeded in sending messages from England to Newfoundland. The radio waves had carried across the Atlantic!

Marconi's success was largely due to the fact that he worked by the scientific method. He had a clear idea of what he hoped to accomplish, namely, to discover a method of sending messages long distances by wireless telegraphy. To throw light on his problem, he read about the work of other scientists. From several possible solutions, he selected the one that appeared to him the most promising — the use of electromagnetic waves. He tested his ideas by experiments. He improved his instruments, and tested them again and again. He worked hard and systematically. He kept his goal—the long-distance transmission of messages by wireless—constantly before him until it had been reached.

So rapid was the progress in the field of wireless telegraphy that in a few short years radios were bringing music and news bulletins to millions of listeners all over the world. New and better instruments gradually replaced the ones Marconi originally used. Almost every year sees the introduction of some improvement. Today it is possible to have a two-way conversation by means of shortwave radio between such widely separated countries as Canada and England.

Marconi was the inventor of wireless telegraphy — the forerunner of radio. (The Bettmann Archive)



Radio transmission and reception. What happens when the sound waves of the man's voice reach the microphone? How are these vibrations transmitted through the broadcasting station? How are they transmitted through the air to the receiving set on the table? What happens in the receiving set to reproduce the man's voice?

Royal Canadian Mounted Police officers are aided in their work of crime detection by a radio communications system. (General Electric Company photo)

Radio — a means of communication

You will remember that a simplified telephone system consists of a transmitter, a receiver, and a source of electricity connected by telephone wires. In some respects, communication by means of radio is similar to the telephone. For example, there must be a mechanism by means of which the message is sent. It is called the *transmitter*. In both the radio and the telephone transmitter, sound waves produce variations in the strength of the electric current. The device used in the radio transmitter to change sound waves into a varying electric current is called a *microphone*. The varying electric current is carried from the microphone, usually by telephone wires, to the transmitting station, which may be several miles away. The radio transmitter sends out *radio waves* in all directions into space. Study the diagram on page 231.

Radio waves travel in slightly curved lines and with the speed of light, that is, 186,000 miles per second. Radio waves that travel upward into the atmosphere soon encounter layers of electrified particles that reflect them back to the earth's surface. From here, the radio waves are again reflected into the atmosphere. Because of their bouncing, zig-zag course between the earth and the upper atmosphere, radio waves strike the earth at intervals and can usually be picked up at great distances from the transmitter.

SOMETHING TO DO

Visit a radio repair shop. Ask the person in charge to show you the main parts of a receiver and explain to you the purpose of each.

When radio waves strike the antenna of a radio receiving set, they produce similar waves in the antenna.

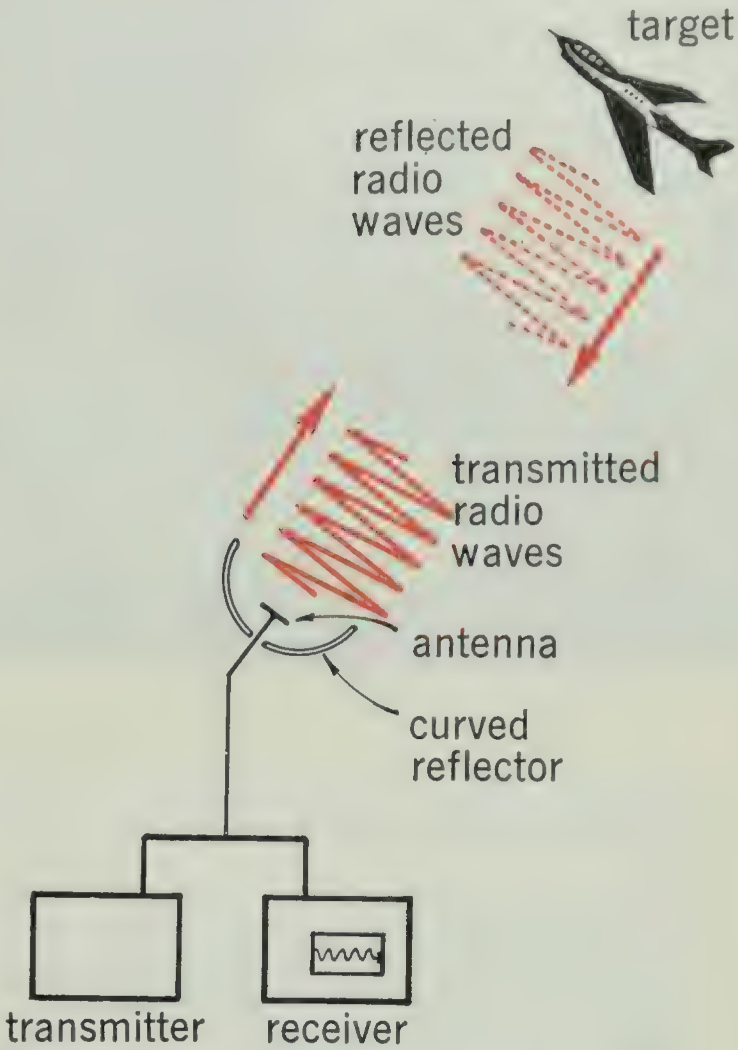
In the radio, the waves are strengthened by radio tubes and changed into a varying electric current. The current is led to the loud speaker of the receiving set, where it causes the *diaphragm* to vibrate and produce sounds similar to those that entered the microphone in the broadcasting studio. As you listen to your radio, you hear a clear reproduction of the program being performed in a studio that is possibly hundreds of miles away.

Radar — an aid to safe travel

Radar is a device that uses radio waves to locate objects through dense fog and clouds. It operates effectively either in daylight or in darkness.

A radar station uses both a transmitter and a receiver. The transmitter sends out radio waves that are focused into a narrow beam and travel at the speed of light. If they strike a ship or airplane or other object, they are reflected back and are picked up by the receiver. The distance from the radar station to the object struck by the radio wave can be determined by calculating the time it takes a wave to travel to the object and return to the station.

Radar is very useful in helping ships and airplanes to navigate safely through fog and clouds. By means of radar, icebergs, shorelines, mountains, other ships, and airplanes can be located and identified. Such information is vitally useful to navigators in piloting ships and planes to their destinations. Radar is also used in locating and following the course of rain- or snowstorms.



By means of a radar set, the presence of an airplane can be detected before it can be seen. Note how radio waves that are sent out by the transmitter strike the target and are reflected back. How is the distance to the target calculated?

Deep-sea fishermen sometimes use radar to locate schools of fish.

Radar contributes, too, to safe travel on land, as it is being used more and more by traffic officers to check the speed of automobiles on our highways.

In wartime, radar is widely used to detect the approach of enemy planes and ships a hundred miles or more away. It can also be used to aim anti-aircraft and naval guns automatically.

Three types of radar height-finders. Left: A mobile radar unit. Centre: Dome-shaped structure called a *radome,* which is used to house radar equipment in Arctic climates. Right: Radar unit suited for permanent installations in temperate zones. (General Electric Company photo)

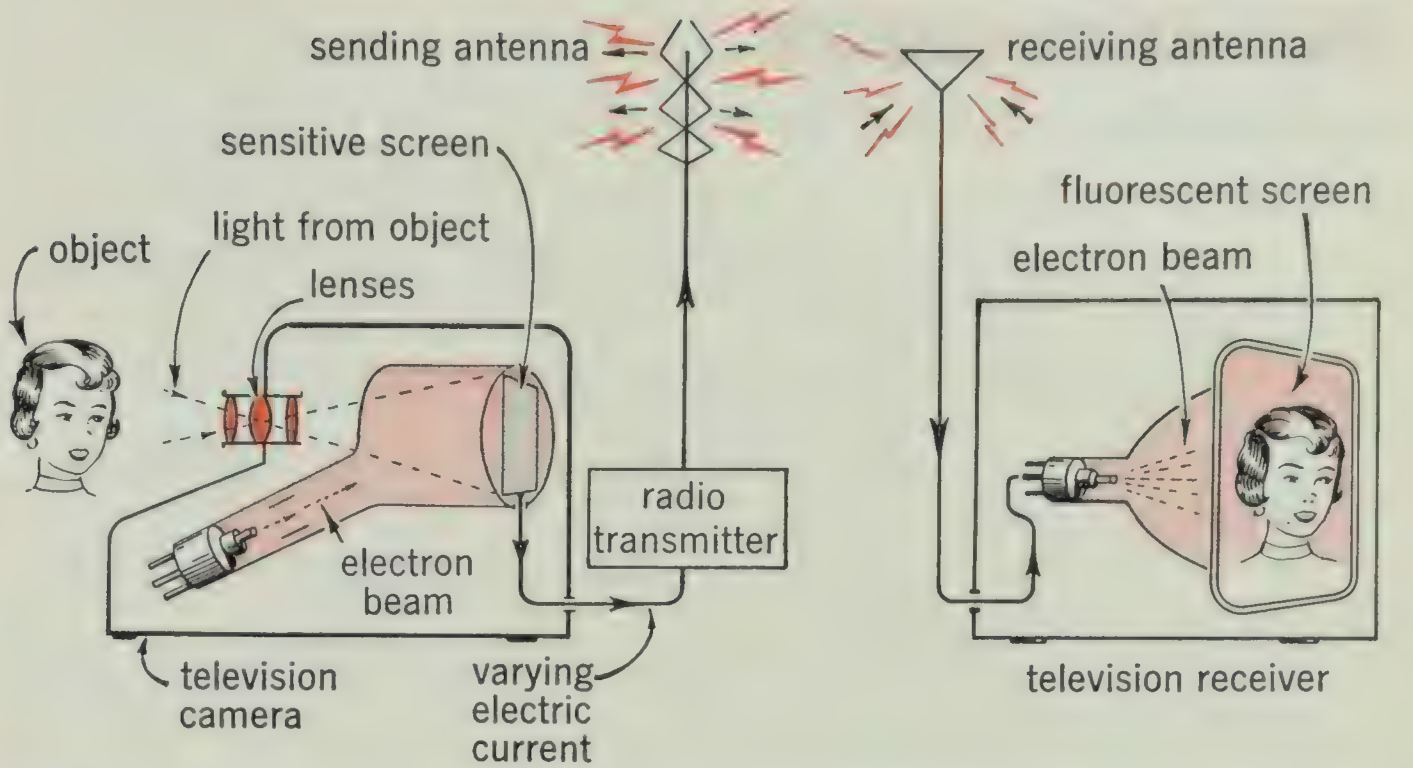
Communication by television

The scientists who invented the telegraph, the telephone, and the radio made possible rapid communication over great distances. Since 1925, scientists have produced and improved another remarkable device for transmitting not only sounds but also pictures. This latest means of communication is *television,* or TV. By means of television, we are able to see important events at the instant they are taking place, possibly thousands of miles away, and to hear the sounds that are associated with those events.

As with radio, television makes use of a *transmitter* and a *receiver.* A television station has two transmitters actually, one for sound, the other for pictures. The sound is picked up by a microphone and changed into a varying electric current, which, in turn, is changed into radio waves. The latter are transmitted in much the same way as in radio broadcasting. See the diagram on page 235.

In developing television to broadcast pictures, scientists made use of the fact that light energy can be changed into electric energy, and vice versa. Reflected light from the object being televised is focused on a *sensitive screen* in the television camera, where it forms an image. An *electron gun* in the camera throws a narrow beam of electrons over the image on the screen, producing a *varying electric current.* The varying electric current is amplified, or made stronger, then sent out as *radio waves* from the *antenna* of the transmitter.

Let us suppose that a girl wearing a white blouse and a dark skirt is being televised. You will need to understand that white material reflects more light than does material of dark shades. Because of this, a stronger light will be reflected from the girl's blouse than from her skirt. When this



Television transmission and reception. Explain how the picture of the girl is transmitted and reproduced on the screen of the television receiving set.

stronger light falls on the sensitive screen of the camera, it causes a stronger flow of electrons than does the less intense light from the skirt. The result is that the image of the girl being televised is changed into patterns of electrons. These, in turn, are changed into radio waves which carry the picture, piece by piece, to the receiver.

The radio waves are picked up by the antenna of the receiver. They are changed to electric waves and carried into the *picture tube*. This causes a beam of electrons to play on the screen of the receiver. The screen is covered with a chemical that changes the electricity back into light. In this way, the picture is formed on the fluorescent screen of the set.

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. Using the story of Marconi as an example, show how scientists follow the scientific method in solving problems. In preparing your answer, refer to the steps in the scientific method as outlined on pages 14 and 17.
2. How is a radio message transmitted?
3. How are radio waves changed into sound waves in the receiver?
4. Explain how radar is used as an aid to safe travel.
5. Name four methods of rapid communication made possible by the use of electricity. State a special advantage of each method.

WHAT HAVE YOU LEARNED?

IMPORTANT SCIENCE IDEAS AND UNDERSTANDINGS

A

1. Electricity is generated by changing some other form of energy into electrical energy.
2. An electrical voltage is produced in an electrical conductor when it moves through a magnetic field.
3. An electric generator is adapted for large scale production of electrical energy.
4. Two forms of current electricity are used: alternating current and direct current.
5. An electric motor is designed to change electrical energy into mechanical energy.

A studio in a television broadcasting station. Which man is being televised? Which men are operating the cameras? Notice that the microphone is attached to a long metal boom which can be moved about quickly. (Canadian General Electric photo)

6. By harnessing waterfalls, by burning coal or oil, or by using atomic energy, man has been able to produce electrical energy to do much of his work.

7. Many steps are required to make the energy of a river or of fuel available as electrical energy in the home.

8. The flow of electricity in a home is controlled by means of switches.

9. Fuses or circuit breakers are inserted in electrical circuits to protect buildings in case of over-loading or short circuiting.

10. Electricity can be dangerous if safety devices and precautions are ignored.

11. Electric power is measured in watts or in kilowatts.

12. Electricity flowing through a resistance produces heat and sometimes light.

13. Electricity has lightened and speeded up our work.

14. Electricity is used in the rapid transmission of messages by telephone, telegraph, radio, and television.

15. Electricity is an aid to safe travel through its use in traffic signals, and highway lights, in radar control of speeding, and in other ways.

(a) The foregoing sentences are all true statements of important science ideas and understandings. Read and discuss them carefully as a review of this chapter.

(b) The following sentences describe situations in which some of these ideas apply. To test your ability to apply ideas to actual situations, match sentences in A with situations in B to which they apply.

B

1. Roger Forbes discovered that the cord used with the electric toaster in his home was badly frayed. He repaired it by wrapping insulating material around the bared wires.

2. An elderly lady visiting in her granddaughter's home observed that housekeeping today is quite different from what it was when she was a young girl. In the "old days" she used a broom or a hand-operated carpet sweeper to clean the carpets; her granddaughter has an electrically operated vacuum cleaner to clean the rugs. The elderly woman washed clothes by hand, using a washboard in a tub of water; today an electric washing machine takes the drudgery out of her granddaughter's "wash day." The visitor felt that times had certainly changed.

3. Charles Parker, who lives in Red Deer, Alberta, was watching a hockey game on TV that was being broadcast from the Maple Leaf Gardens in Toronto. Even though Charles was over 2000 miles away, he was able to see the highlights of the game at the instant they occurred.

4. Yvonne Carter filled a tea kettle with water, placed it over an element of the electric range, and turned on the switch. Soon the water in the kettle was boiling.

5. Ruth Kelly arrived home at night to find the house in complete darkness. She flipped the snap switch near the door and immediately the front hall was flooded with light.

6. Frank Selley was studying the electric meter in his home when his mother started to polish the waxed floor with an electric floor polisher. Frank noticed that the hands of the meter began to move faster.

7. Two girls in Mr. Kennedy's class were experimenting with a simple Voltaic cell. When they closed the circuit by connecting the zinc plate with the copper plate by means of a copper wire, their compass showed that an electric current was flowing through the wire. They also observed that the zinc plate was being eaten up due to the chemical action that was taking place in the cell.

8. Linda Goodman reported that she had read in a science text that an electrical voltage can be produced by causing a coil of wire to rotate between the poles of a strong magnet.

IMPORTANT SCIENCE TERMS

A

electric generator	transformer	nichrome
dynamo	fuse	radio
armature	circuit-breaker	transmitter
field magnet	electric switch	receiver
alternating current	short circuit	carrier wave
direct current	watt	radio wave
commutator	volt	antenna
turbine	ampere	varying electric current
penstock	kilowatt	radar
transformation of energy	resistance wire	television

To show that you understand and can use the science terms listed in A, match with the situations described in B those terms which apply.

B

1. Marie Lucas held a large magnifying glass in such a way as to focus the sun's rays on a sheet of paper. The paper took fire.

2. Gary Morin overloaded the circuit in his bedroom by operating too many electrical appliances at one time. The lights went out.

3. In constructing an electric motor, John Thompson wound insulated wire many times around a U-shaped piece of soft iron.

4. Mary Jones was about to do some ironing. She did not notice that, due to the fact that the insulation had been worn away, the wires of the cord near the plug were bare. When she plugged the cord into the electric circuit, there was a flash of light accompanied by a spitting noise.

5. While motoring along the highway, Howard Kovac read a traffic sign which stated that a scientific means of checking on speeding was being used.

6. Mr. Kennedy's science class went on a field trip to the local electric power station. They noticed a huge pile of coal at the power plant and wondered why it was there. A supervisor told them that the electric power developed in the plant was obtained by burning coal.

SCIENTIFIC METHOD AND ATTITUDES

1. Charles Parker was making a report to his class on the sources of electricity. He quoted the following statement from a science article that he had read: "Regardless of whether your electricity comes from water power or from coal or oil it is captured sunlight just the same." This started a discussion among the members of the class. In which of the following situations would a pupil be showing a scientific attitude:

(*a*) If he flatly stated that the statement was wrong and refused to discuss the matter any further?

(*b*) If he asked Charles who it was who had made the statement and whether that person would be in a position to know?

(*c*) If he decided to check several science textbooks to find out whether any of them made similar statements, and, if they did so, to accept the statement as fact?

(*d*) If he investigated to find out whether the sun is responsible for water being carried to higher land, and whether sunlight

was necessary for the growth of the plants and animals from which coal and oil were formed?

2. A group of boys were watching the Grey Cup football game on Fred Darrow's television set. At a most exciting stage of the game the picture flickered, then faded out.

"I knew it," said Fred. "Something always goes wrong with our TV set just when things are getting exciting. But I'm not too surprised; I broke a mirror this morning, so I knew I'd run into bad luck sometime today for sure."

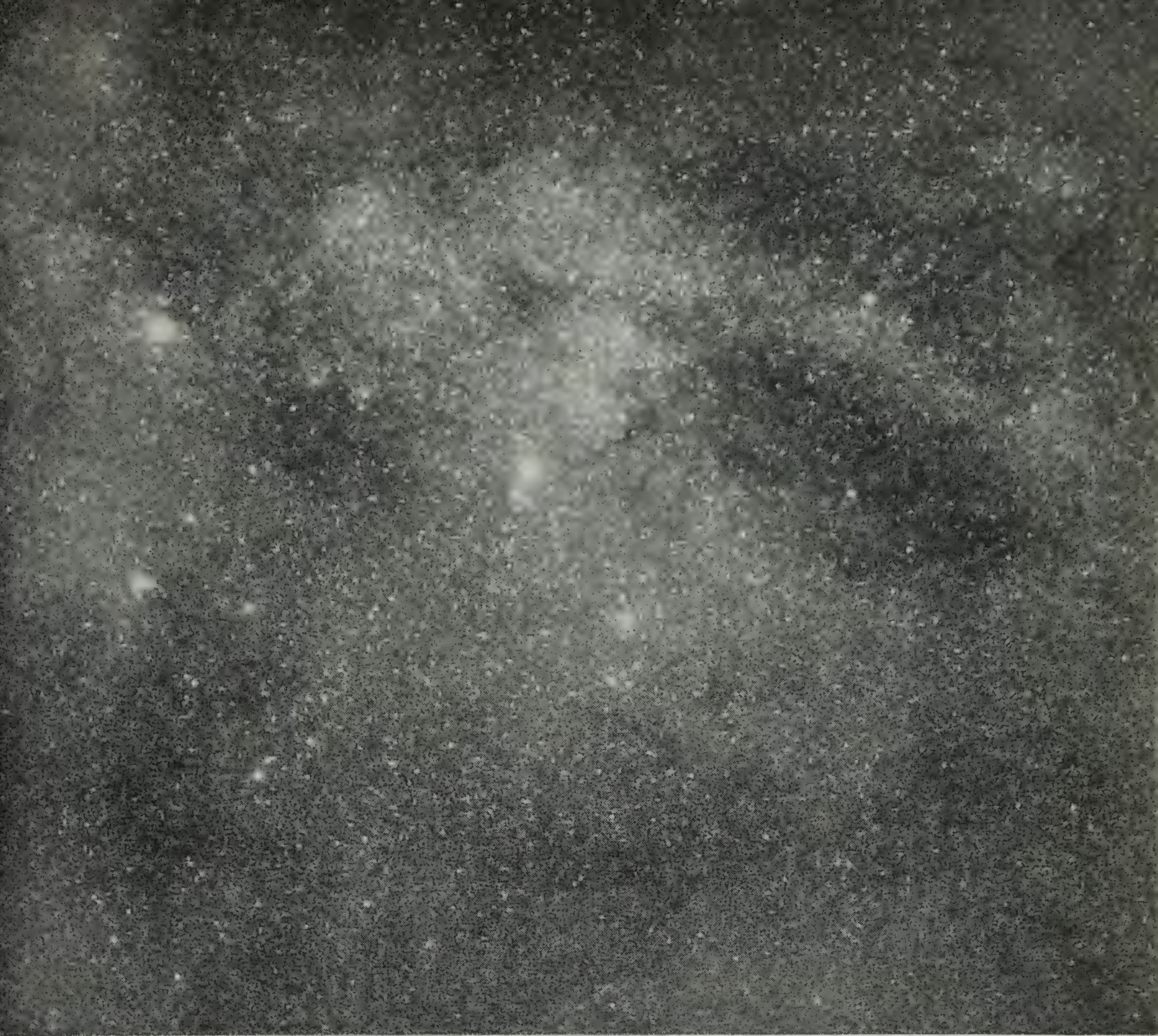
"Maybe there's nothing wrong with your TV set. It may be that there's trouble at the broadcasting station," suggested Earl.

"Or it could be that a loose connection has developed somewhere in the instrument. Perhaps your Dad can fix it, Fred," commented Walter.

"Phone home, Bill, and find out if your TV set will pick up the Grey Cup game from the same broadcasting station," urged Peter. "I think we should consider all possible causes of failure in reception before blaming Fred's TV set for all the trouble, or taking any steps to repair it."

(*a*) Which boys showed a scientific attitude in the situation described? Which boys did not? Why?

(*b*) State the two steps of the scientific method which are evident in the TV situation described above.



Yerkes Observatory

The sad and mournful night
Hath yet her multitude of cheerful fires;
The glorious host of light
Walk the dark hemisphere till she retires;
All through her silent watches, gliding slow,
Her constellations come, and climb the heavens, and go.

—*Bryant*

CHAPTER 6

CHAPTER 6

OTHER WORLDS AROUND US

Sometimes, as we look out from our earth to the sun, moon, and stars, we wonder how such distant worlds can have any meaning or use to us. However, scientists have found out many things about the universe. They know, for example, that the sun is a star, but not the largest of the millions of stars. How is the sun useful to us? Have you ever wondered why the seasons change, why summer days are long, and what causes the phases of the moon? Can you use the sun and the stars to tell direction? How would you tell time by day and at night without a watch? Have you ever seen an eclipse? Learning to recognize constellations is an interesting activity. How far away are the stars? Do you think that space travel will ever be possible?

Astronomy, the study of the sun, moon, planets, stars, and other objects in the sky, is the oldest branch of science. Thousands of years ago, before man began to organize his knowledge of plants, animals, rocks, and weather, he formed and tested many ideas about the bright objects seen in the sky.

It is surprising how much early man learned about astronomy. For example, over 3000 years ago the Chinese learned to predict eclipses. The Egyptians, in building their pyramids, showed an exact knowledge of the position of the sun and stars at different times of the year. From the position of the stars they predicted accurately the annual flooding of the Nile river. They also erected tall, slender towers to serve as sundials. The ruins of an ancient temple at Stonehenge, in England, provide proof that early Britons also recorded accurately the position of the sun at different times during the year.

Early astronomy, however, also included many errors. Because people had no telescopes or other scientific equipment to aid them in their

observations of the heavens, they often reached conclusions that we know are false. For example, they often regarded the sun and stars as gods. It is little wonder that early man worshipped the sun that appeared each morning to provide him with light and warmth. It is not surprising that he also regarded with fear and respect the stars that marked the night sky. From early Greek and Roman studies of the sky we acquired the names of most of the planets, and of the constellations, or groups of stars in the night sky.

Out of early man's respect for the stars there developed a false science called *astrology*, which tries to show that people's lives are affected by the position of the planets and stars at the time of year when they were born. Although most people today realize that astrology is a false science, astrology columns, or horoscopes, still appear in many newspapers, and some people still try to predict and plan their future by the stars.

Early man made another serious error in his observations of the universe. It seemed to him that the earth was in the centre, and that the sun, planets, and stars travelled around the earth. Nearly 2000 years ago, an Egyptian astronomer named Ptolemy described a theory of the universe in which he said that the earth remained still and that the moon, sun, and stars moved in circles around it. Almost everyone accepted Ptolemy's theory, and for 1500 years it remained unchallenged.

About the year 1530, a young Polish astronomer named Copernicus made many careful observations of the stars and sun, and as a result he formed a new theory. He said that the earth was one of several planets revolving around the sun, and that the earth rotated on its own axis once each day. This new Copernican theory was not readily accepted, but it eventually proved to be correct.

A Dutch eyeglass maker, Lippershey, and a famous Italian scientist, Galileo, made important contributions to astronomy when they invented and improved the telescope. With this aid to observation, Galileo was able to study the heavens more accurately. He noticed, for example, that Jupiter, the largest of the planets, had moons revolving around it. In fact, he discovered four of Jupiter's moons. From this and other observations he proved that the Copernican theory was correct. In time, people came to accept the new idea that the sun, and not the earth, is the centre of the solar system.

With the invention of the telescope, astronomy made rapid progress. An English mathematician, Isaac Newton, aided astronomy by discovering that the force of gravity that makes objects fall, also holds the earth and other planets in place as they travel around the sun (see page 275).

Today the astronomer has many scientific instruments to help him test his ideas about the universe. Giant telescopes enable him to study heavenly objects clearly. Photographs of the moon, planets, and eclipses

Nicolaus Copernicus, the son of a Polish baker, was born in 1473. His interest in astronomy led him to investigate the old idea that the earth was the centre of the universe. After thirty years of study, he concluded that the sun is the centre of the solar system, with the planets revolving around it. Copernicus is often called "the father of modern astronomy." What did one writer mean when he said that Copernicus "found the key to the clockwork of the sky"? (International Nickel Company of Canada)

provide useful information. Special cameras provide him with information about the chemical content of the stars. New radio telescopes help him to locate stars far out in space. Rockets help him to test conditions in and beyond the earth's atmosphere. In recent years, man-made moons, or satellites, have enabled the scientist to test his ideas about outer space, and to gain much new information about conditions in the vast space between the earth and her neighbors in the universe.

In the years ahead, as scientists improve present instruments and invent new ones, we shall learn much more about the planets and stars.

THE SUN, OUR DAY STAR

Did you know that the sun is a star? Although it appears much larger, brighter, and hotter than the other stars, it is really only a middle-sized star. It is only because it is much closer to us than the other stars that it seems so large and bright. If the sun were as far away from us as many of the other stars that we observe on a clear night, it would seem like an ordinary star.

The sun is the star most useful to us

We are fortunate to be located in space near enough to the sun to receive benefits from it, but not so near as to be destroyed by its heat.

The most important gifts from the sun are *light* and *heat*. The sun provides us with almost all our light. What a dark world this would be without sunlight! This gift from our day star is required by our bodies to keep us healthy. Sunlight is the source from which plants obtain the energy needed by the chlorophyll in their leaves for the production of starch and sugar. Thus, most of our food and clothing, and much of our shelter, is made possible by sunlight. Without warmth from the sun, plant and animal life could not exist on the earth. All water would remain as ice. The temperature on the earth would likely be more than 400 degrees Fahrenheit below zero.

The heat and light provided by the sun supply us with several forms of *power*. Coal and oil, which have been formed from plants and animals that lived long ago, contain the energy of sunshine stored up by these plants and animals when they were living. When we burn coal and oil to produce heat and power, we are really using "buried sunshine."

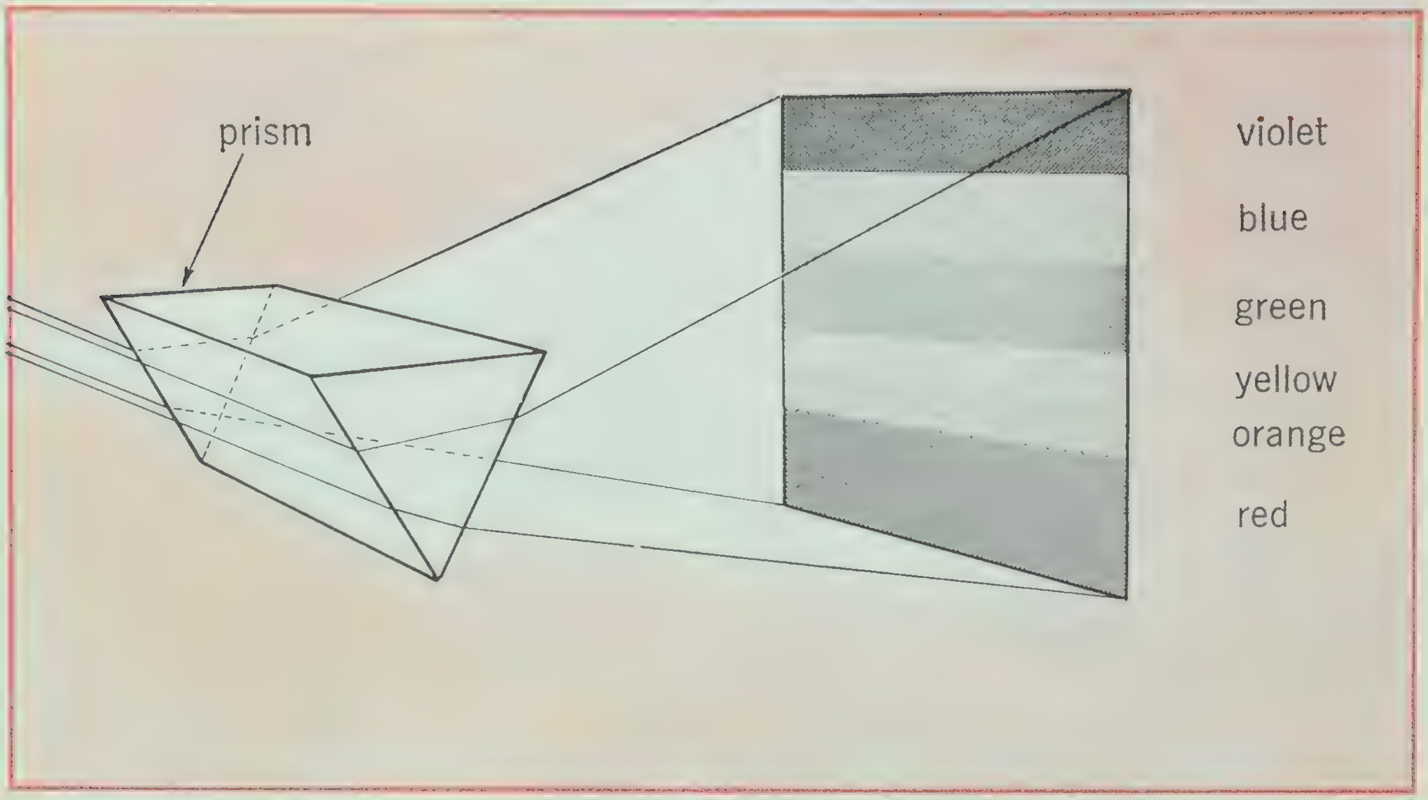
The sun also makes possible the production of electricity. As you know, heat from the sun causes water to evaporate and become water vapor. Later, when the water vapor condenses and falls as rain, it fills the streams that flow downhill, turning the giant turbines that produce electricity.

Because energy from the sun is stored up in foods manufactured by plants, our body warmth comes indirectly from the sun. The food we eat is changed to heat energy as it is oxidized in the cells of our bodies.

In addition to supplying power and giving us light and heat, and making it possible for plants to produce our food, the sun affects our lives in other ways. It is responsible for changes in the *weather* – for wind, rain, and snow, and even for the clouds that sometimes hide the sun from our sight. Then, too, the sun makes our world beautiful by giving us the gift of *color* seen in trees and flowers, birds and butterflies, water and brilliant sunsets.

SOMETHING TO DO

Place a glass *prism* so that direct sunlight shines through it. The band of colors



When sunlight passes through a glass prism, the colors are separated, forming a spectrum. Notice the order of the colors, and the width of each. Compare this with the colors in a rainbow.

that is formed is called a *spectrum.* Name the colors in order. Sunlight contains all these colors. They are separated to form a spectrum when sunlight shines through the prism. Compare the colors of the spectrum with those shown in the drawing on this page.

If a glass prism is not available, a rectangular aquarium full of clean water may be substituted. Place the aquarium on a window ledge where direct sunlight shines through it. Move the aquarium until a spectrum is seen on the floor or wall. Carefully observe the colors of the spectrum.

Watch for the appearance of a spectrum in the sky during or following a rainstorm. When sunlight shines through a shower of raindrops, the colors are separated to form a *rainbow.* Compare the order of the colors in a rainbow with those formed by the glass prism or the aquarium.

What is known about the sun?

When we look at the sun, it is hard to realize how huge it is. The best way of gaining an understanding of its great size is to compare it with the earth, which is a much smaller sphere. Imagine that the earth is a ball slightly smaller than a golf ball, that is, about 1 inch in diameter. In comparison, the sun would have to be represented by a ball 9 feet in diameter! How many times is the diameter of the sun greater than the diameter of the earth?

Although the sun is our closest star, it is nevertheless a very great distance from the earth. Scientists have found that the average distance to the sun is about 93,000,000 miles. If you wanted to represent the distance between the earth and the sun, using the 1-inch

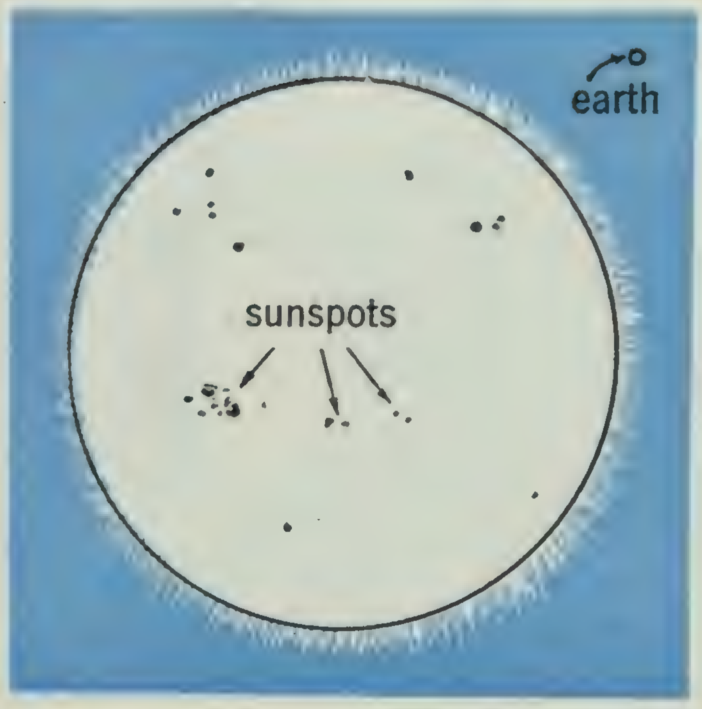
ball and the 9-foot ball, they would have to be placed 1000 feet, or nearly ⅕ of a mile, apart.

SOMETHING TO DO

Today, we frequently see or read about jet planes that are capable of travelling 600 miles per hour. How far could such a plane travel in 24 hours (one day)? How many days would be required for it to travel 93,000,000 miles? How many years would that be?

You very likely found that a jet plane, travelling continuously at 600 miles per hour would require about 18 years to travel a distance equal to the distance between the earth and the sun. Now do you realize that, although the sun is our closest star, it is, nevertheless, a vast distance from us? You will also realize how great the speed of light must be to travel from the sun to us in only 8½ minutes. Is it surprising to learn that the rays of light illuminating the objects you see at the present moment left the sun such a few minutes ago? Light travels at the remarkable speed of 186,000 miles per second!

The sun is so hot that its temperature is much greater than most temperatures we have on earth. At the surface of the sun, the temperature is probably about 10,000° F., but in the centre it may be as hot as 27,000° F. Because of the heat, the substances of which the sun is made are in the form of gases. Scientists today believe that the sun's heat and light are produced by the release of the *atomic energy* from some of the



A comparison of the sizes of the sun and the earth. How does the earth's size compare with the size of some of the largest sunspots? Notice the great distance to which glowing gases extend above the sun's surface.

gases. From time to time, great storms seem to occur on the surface of the sun. From the earth these storms appear as dark areas. We call them *sunspots*. Although we do not know the nature of sunspots, we do know that when they are severe they affect our radios, compasses, and weather.

What causes day and night?

We all speak of the rising of the sun in the east in the morning, and its setting in the west each evening, as if the sun really were moving around the earth each day. Early man believed that the sun actually moved around the earth; even today many people think the same thing.

For many years, man has known that the earth is round like a ball. What proof of this have you seen? Scientists have also learned that the

This diagram illustrates how day and night are caused by the daily rotation of the earth. How much of the earth can have daylight at any one time? Why?

earth *rotates,* or spins around once every day or twenty-four hours. The imaginary line passing through the earth, around which it spins, is called the *axis* of the earth. The earth rotates *from west to east* on its axis.

As the earth rotates, we cannot feel its movement, because it turns so smoothly. When you travel along the road in a car, or drift downstream in a boat, it may seem that trees and buildings are moving toward you. However, you know that they do not move. Likewise, the sun does not move around the earth each day, but only seems to do so as the smoothly moving earth rotates.

SOMETHING TO DO

1. With colored chalk mark the location of your community on a globe. Make your classroom as dark as possible. Shine a flashlight on the globe, to represent the sun's light. Slowly rotate the globe but do not move the flashlight. Is your community always in sunlight? About how much of each day is daylight? How much of the earth is lighted by the sun at any time? Turn the globe to show morning, then noon, then evening, then midnight in your community.
2. Note the path that the sun seems to follow across the sky by observing it several times during the day.

You have seen that, as the earth rotates, first one side and then the other is turned toward the sun. When our side of the earth faces the sun, we have daylight; when it is turned away from the sun, we have night. Thus we see that the daily rotation of the earth causes day and night.

TEST YOUR KNOWLEDGE AND UNDERSTANDING

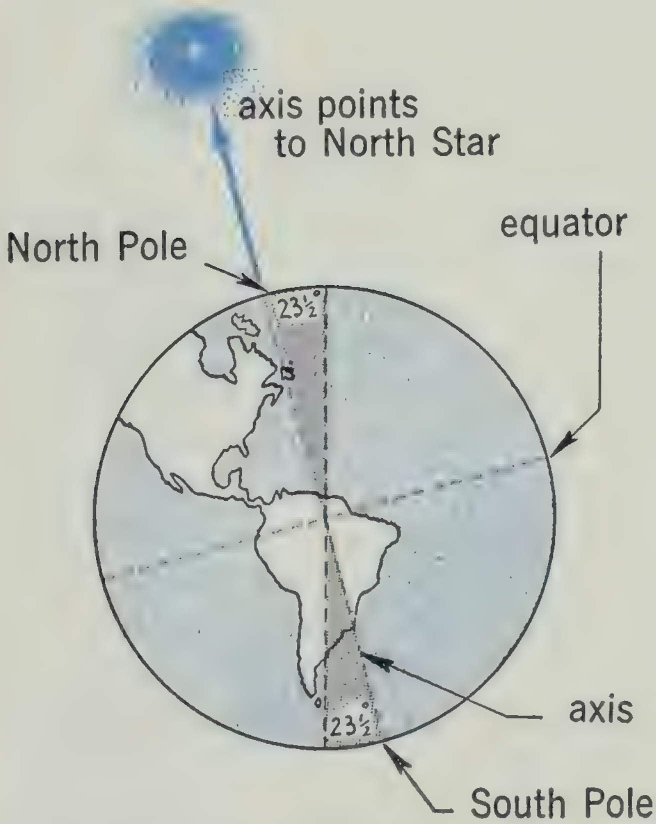
1. Explain two ways in which the sun is essential to us.
2. What do we mean when we call coal "buried sunshine"?
3. Explain how the sun helps to produce electricity.
4. What is meant by a spectrum?
5. Compare the sizes of the earth and the sun.
6. What do scientists think the sun is made of?
7. Explain why the sun seems to rise in the east and set in the west.
8. What causes day and night?

CHANGES IN THE SUN'S POSITION IN THE SKY

Does the sun always appear to be following the same path across the sky, or does its apparent path change during the year?

SOMETHING TO DO

1. Once a week for several weeks, observe the sun's position in the sky at sunrise, at noon, and at sunset. What changes did you notice?
2. Measure the length of your shadow at noon once a week for several weeks. What did you find out?
3. On a south window, paste a piece of cardboard with a small hole in it through which the sun can shine. Fasten another paper on the window sill or on the wall at some distance from the window, so that the light shining through the hole falls on it. At the same time each day, mark the outline of the position of the light patch, and mark down the date beside it. Continue this for a month. What changes are noticed? Why did these changes occur?



The axis of the earth tilts at an angle of 23½° away from a vertical line. Compare this drawing with a globe, to see if the globe is tilted in the same way.

You have observed that the sun's apparent path across the sky changes slightly from day to day. About December 21, the sun is at its lowest point in the southern sky. From then until June 21 it rises slightly higher each day. About June 21 it is at its highest point in the sky. Then from June 21 to December 21 its position in the southern sky is slightly lower each day.

What causes changes in the sun's position in the sky?

Why does the sun's position become higher each day from December 21 to June 21, and lower from June 21 to December 21?

SOMETHING TO DO

Examine your classroom globe. It is constructed to show the earth's axis exactly as it is. Rotate the globe on its axis. Is its axis vertical?

You have seen that the axis of the earth is not vertical. It is tilted at an angle of 23½ degrees.

Each year, our earth travels once around the sun. The path, or *orbit* along which it travels is a slightly flattened circle. Each *revolution*

around the sun takes about 365¼ days, or one year.

SOMETHING TO DO

Place a light, such as a bright bulb, which shines in all directions as the sun does, in the middle of the room. If necessary, use a flashlight. Darken the room as much as possible. Walk around the room once, carrying the globe, which represents the earth. Keep the globe spinning from west to east as you go. One trip around the "sun" represents a year on the earth, and each spin of the globe represents one day.

Now hold the globe so that the axis is tilted toward the north. Walk around the "sun," *being sure to keep the axis tilted toward the north,* just as the axis of the earth is tilted so that it points toward the North Star. Notice where the rays of the "sun" shine most directly.

At one part of the revolution around the "sun," you probably noticed that the North Pole, which is the north end of the earth's axis, leaned toward the "sun." This position of the earth's axis coincides with our calendar date of June 21.

Stop the movement of the globe at the June 21 position. (The globe should be south of the "sun" in your classroom.) Locate your community on the globe, and turn the globe so that your community is at the noon position. Does the "sun" shine almost directly upon it? As seen from your community, how high in the sky would the sun be at noon at this season? You may mark your community's location with a pin. How long is the pin's shadow? Why is it very short?

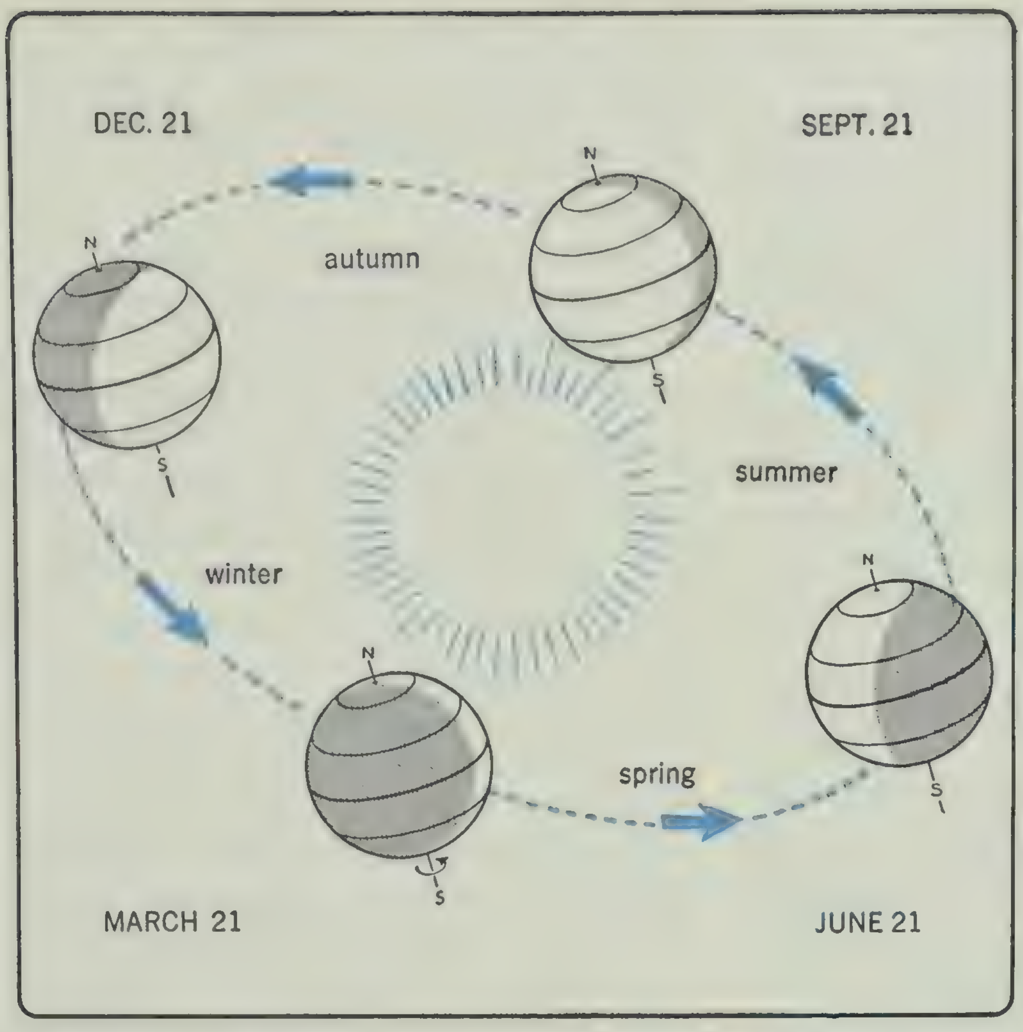
Carry the globe one-quarter of the way around the room, *making sure that the axis is still tilted toward the north.* Stop the globe at the noon position for your community. Where do the direct rays of the "sun" fall now? This is the September 21 position, when the sun is directly over the equator. Find the equator. As seen from your community, how high is the sun in the sky at noon? How does the sun's position on September 21 compare with its position on June 21? Examine the pin's shadow. What does the longer shadow tell you about the sun's position in the sky?

Again carry the globe one-quarter of the way around the "sun," *keeping the axis tilted to the north as before.* You have now reached the December 21 position. Notice that the North Pole is tilted away from the sun. Turn the globe so that the pin marking your community is in the noon position. Where do the most direct rays of the sun fall? From your community, what is the sun's position in the sky at noon? What does the very long shadow of the pin show you?

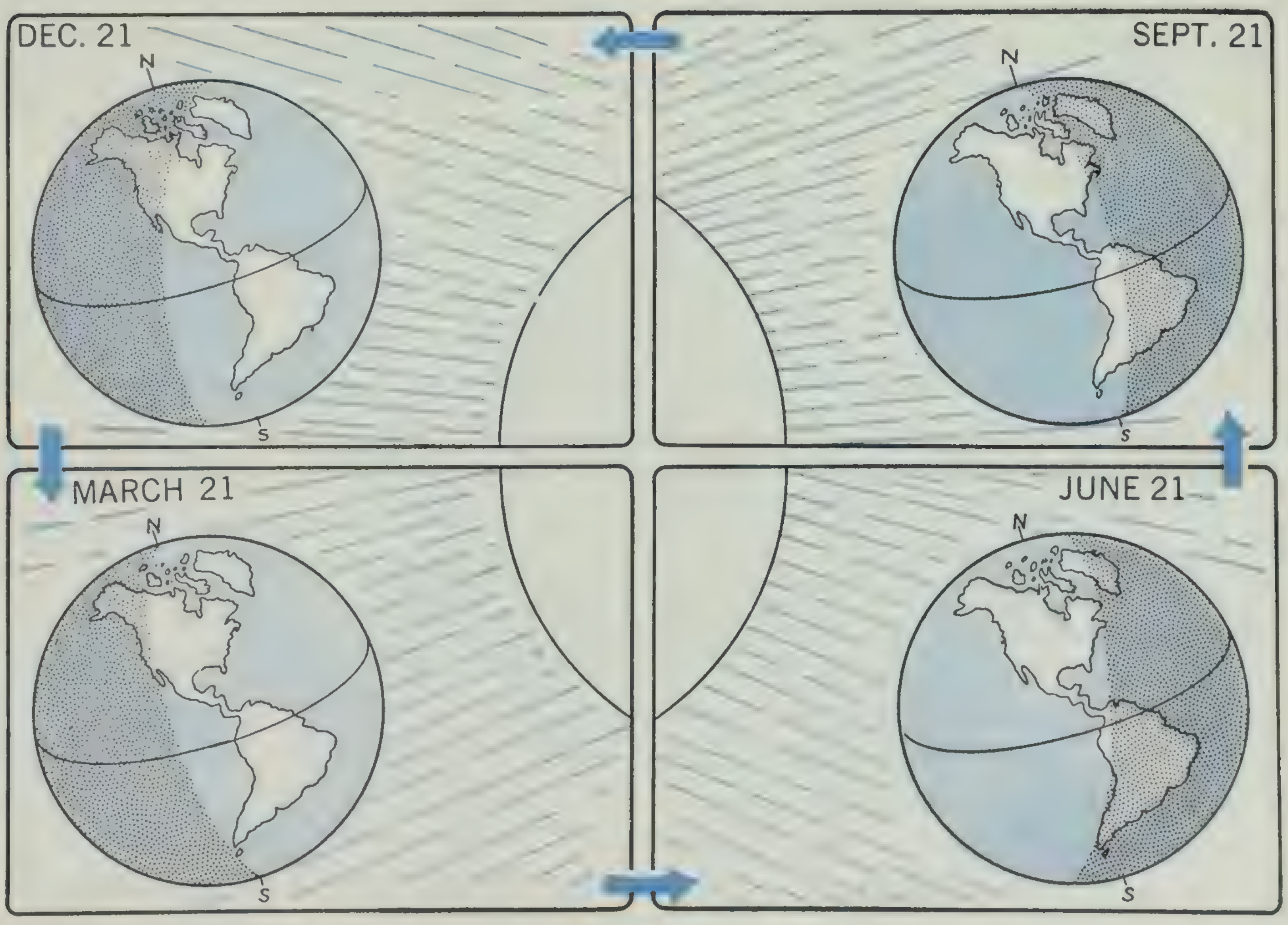
Again carry the globe one-quarter of the way around the "sun." Now you are at the March 21 position, when the sun again shines directly down on the equator. As seen from your community, what has happened to the sun's position in the sky?

Carry the globe the remaining one-quarter of the way around the circle, bringing it to the June 21 position again. *Repeat your observations.* Remember to *keep the axis of the globe always tilted in the same direction, toward the north.*

Because the earth is tilted at the same angle throughout its yearly revolution around the sun, our northern *hemisphere* is tilted toward the



Throughout the year the earth's axis remains tilted in the same direction. As a result, the northern hemisphere is tilted toward the sun on June 21, and is tilted away from the sun on December 21, as shown in the upper diagram. Study the diagrams on this page, and perform the activities described on pages 249-253, to help you understand why we have longer periods of daylight in summer than in winter, and why the sun is higher in the sky in summer than in winter.



sun in summer and away from the sun in winter. On June 21, when the North Pole is tilted toward the sun, the sun is high in the sky. Then, as the axis is tilted less and less toward the sun, the sun's position becomes lower and lower. Finally, on December 21, the axis is tilted away from the sun, and the sun's position is very low in the southern sky. As the axis again becomes tilted toward the sun, the sun's position becomes higher and higher in the sky.

Why are days long in summer and short in winter?

You have noticed that in early summer, daylight begins before we rise in the morning, and continues until nine or even ten o'clock in the evening. Then, during the fall, the sun rises about a minute later each morning and sets earlier each evening, until in winter it rises while we are on our way to school and sets while we are on our way home. Why are days long in summer and short in winter?

SOMETHING TO DO

Set up a flashlight (or light bulb) and globe in a darkened room, just as you did in the previous experiment. Mark the location of your community on the globe with colored chalk.

Carry the globe to the June 21 position, when the North Pole leans toward the "sun." Slowly rotate the globe, observing for how much of each day your community is in daylight. Do you find that it is in "sunlight" for about two-thirds or more of each day? For how much of each day does the North Pole receive "sunlight"? Compare your observations with the illustration on page 251. Do you understand now why the Arctic tundra is sometimes called "'The Land of the Midnight Sun"?

Now carry the globe to the September 21 position and repeat your observations. For how much of each day is your community in the lighted part? For how long is there daylight at this time of the year?

Move the globe to the December 21 position, with the North Pole tilted away from the "sun." Rotate the globe. For how much of each day does your community receive "sunlight"? How many hours of "sunlight" does the North Pole have each day? Have you read of the sunless winters in the land of the Eskimos?

Now move the globe to the March 21 position. Does your community on the globe receive about twelve hours of "sunlight" daily at this season? Move the globe to the June 21 position and repeat your observations. Compare your findings on the globe with the length of daylight in summer, fall, winter, and spring as you have experienced it.

As we know, the tilt of 23½ degrees in the earth's axis causes a great variation in the length of day and night. In summer, when the North Pole leans toward the sun, the northern hemisphere has long days and short nights. The farther north you live, the longer the days are in early summer. During autumn, when the axis tilts less and less toward the sun, the days gradually become shorter. About December 21, when the North Pole is tilted farthest away from the sun, we have our shortest days. The farther north you live, the shorter the

day is in winter. With spring approaching, the days become longer as the North Pole again becomes tilted toward the sun.

REPEAT YOUR EXPERIMENTS

A scientist does not solve his problems by doing an experiment only once. Why? You, too, should repeat these experiments to check the accuracy of your observations about the sun's position and the changes in the amount of daylight we receive at each season.

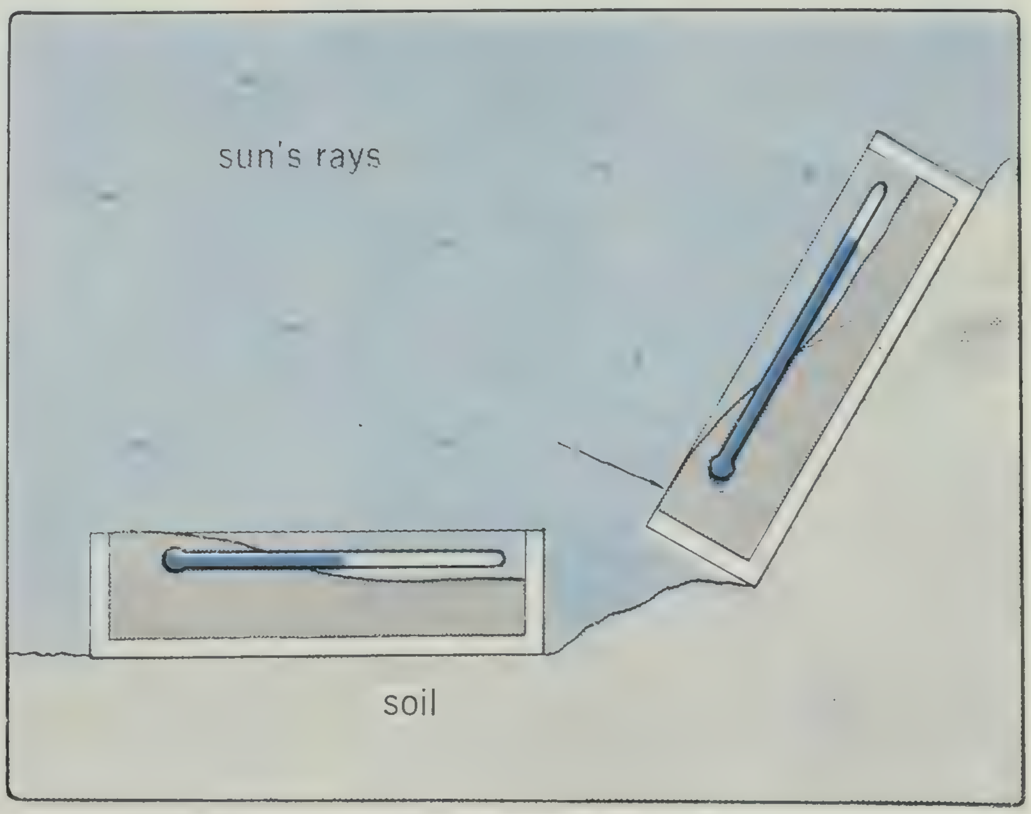
Why is our weather warmer in summer than in winter?

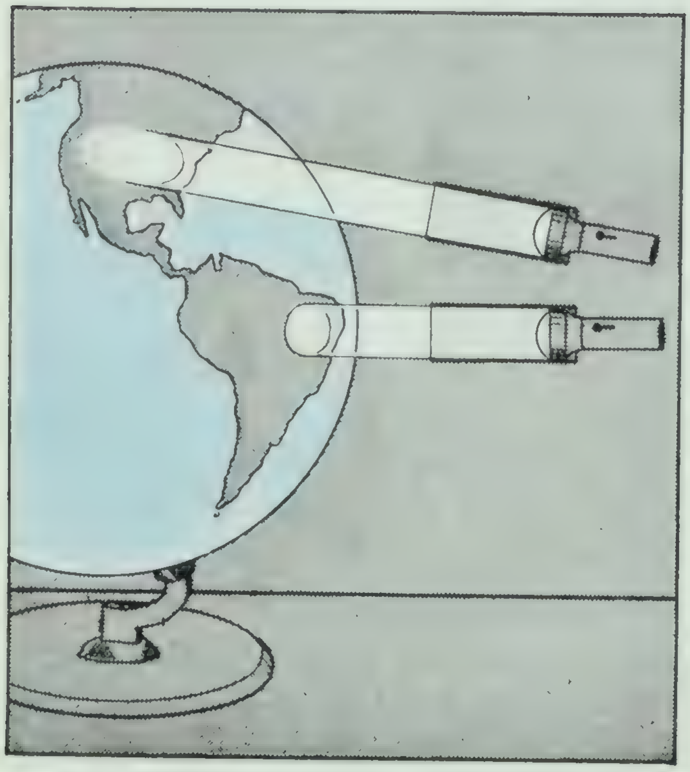
One evening, Fred Blake was reading a magazine article about the seasons. He already knew that the earth revolves once around the sun each year, and that the earth's orbit is not perfectly circular. Imagine his surprise when he learned that the earth is closer to the sun in winter than in summer! Fred wondered, as you probably do, too, why it is warmer in summer than in winter. Fred decided to find out if his classmates could help him solve this problem.

Several of the pupils thought that the earth was closer to the sun in summer, but after checking several science books, they learned that the information Fred gave them was correct – that the earth is farther from the sun in summer than in winter.

Yvonne Carter said she thought that the long summer days made the summers hot. Lillian Dupont said they had learned that the sun shines down more directly in summer, and thought that was the reason for summer being

Do we get more heat from the sun in perpendicular rays, or in slanted rays? Perform this experiment and make your own observations. Why does snow melt more quickly on the south slope of a hill than on level ground?





Although the two beams of light are of equal size, the one that strikes our continent on a slant is spread over a larger area than the one that strikes vertically near the equator. Explain why Brazil is usually warmer than central Canada.

warm. After some discussion, the pupils decided to test Lillian's possible solution to the problem, by doing an experiment to find out if we get more heat from direct rays of the sun than we get from slanted rays.

SOMETHING TO DO

1. Prepare two shallow boxes of dark-colored soil. On a sunny day, place one box so that rays of the sun shine *directly* on the soil, as shown in the drawing on page 253. Place the other box so that the sun's rays strike the soil *on a slant.* Bury the bulbs of two similar thermometers just beneath the surface of the soil in the two boxes. After five minutes check the temperatures. Repeat your experiments several times. What do you conclude about the amount of heat obtained from direct and slanted rays from the sun?

This experiment may also be tried by placing the thermometers under pieces of black cloth on two boards, and placing the boards in sunlight so that the light strikes one directly and the other on a slant.

Did you observe that when perpendicular rays shone on the thermometer, the temperature was higher than when the rays were slanted? In summer, the sun gives us more heat because it is more directly overhead.

2. Obtain a cardboard tube or make a long tube with a piece of cardboard. Use this tube and a flashlight, as shown in the illustration on this page, to compare the area lighted by the beam of light coming from the tube when it shines *directly* on one part of the globe and when it shines *on a slant* on another part of the earth. Which area is brighter? The amount of light and heat in each beam is the same. Which area receives more light and heat *per square mile?*

You already know that in winter the sun's rays that reach us are much more slanted than in summer. You have seen that a slanted beam of light is spread over a larger area than a perpendicular beam of the same size. Each square mile of the larger area receives less light and heat than does each square mile of the smaller area. In winter, the slanted rays of the sun give each square mile less heat and light than it would receive from the more direct rays of the sun in summer. Then, too, the longer daylight period in summer gives the sun more time to heat the northern half of the earth.

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. Explain how the tilt of the earth's axis causes the sun to be higher in the sky in summer than in winter. You should use one or more drawings in your answer.
2. The earth *rotates* once each day, and *revolves* once each year. Explain what is meant by each of these movements of the earth.
3. Describe how you would use a globe and flashlight in explaining to a friend why days are longer in summer than in winter.
4. Describe an experiment to show that we get less heat from slanted rays of the sun than from perpendicular rays. How does this help to explain why our weather is warmer in summer than in winter?

OUR NEAREST NEIGHBOR IN SPACE

The moon is the earth's closest neighbor, but, as yet, man has not been able to visit it. However, in 1946, a group of scientists sent *radar* beams to the moon, and recorded, only 2½ seconds later, the return signal that bounced off the moon's rocky surface. The very short time that radar required to go to the moon and back is an indication that the moon is not far away. It is about 240,000 miles out in space, only about $\frac{1}{400}$ as far away as the sun. The light that you see coming from the moon reaches you in only 1¼ seconds, while that from the sun, as you recall, takes 8⅓ minutes to reach us.

Because it is so close to us, scientists have been able to find out a great deal about the moon. Through the telescope, one can clearly see mountains and plains on the moon. Also, we can see great, round holes on the moon's surface. Some of these holes are many miles across. They look like craters of dead volcanoes, but scientists are not certain what caused them. The holes, mountains, and plains on the moon make the face of "the man in the moon" that you can see when the moon is round and bright.

It is also known that there is no air or water on the moon, so living things do not likely exist there. The temperatures on the moon are very extreme. The side facing the sun is hotter than boiling water, and the dark side has a temperature hundreds of degrees below zero.

The size of the moon has been measured very accurately. Its diameter is about a quarter the diameter of the earth, that is, in size it compares

A comparison of the sizes of the earth and the moon. Compare their diameters. Why is it incorrect to say that the *volume* of the moon is one-quarter that of the earth?

with the earth about as a small orange compares with a basketball. Although the earth's *diameter* is only four times as great as the diameter of the moon, the *volume* of the earth is about fifty times as great as that of the moon.

SOMETHING TO DO

1. Obtain a small orange and a basketball. Place them about 25 feet apart. This shows you the relative sizes of the earth and moon, with the proper relative distance between them.

2. Prepare a calendar by dividing up a page in your record book into enough spaces to show all the days of the month. Mark the dates. Each evening at a certain time (such as eight o'clock), observe the shape of the moon and draw it in the correct space on your calendar. (See the illustration on page 257.) If the moon is not visible in the evening, look for it at eight o'clock the next morning.

3. From your observations of the moon, made at the same hour each night, find out all you can about the movements of the moon.

4. Observe the moon once every half-hour during an evening. Does it appear to move from east to west? Recall our explanation of the apparent movements of the sun. Do you think that the moon is really moving from east to west?

From your observations, you have learned a number of facts about the moon. You have seen that, like the sun, it *appears* to travel from east to west in the sky. However, the moon is not moving from east to west; it only *seems* to be doing so because the earth is rotating from west to east. During an evening, our part of the earth rotates toward the moon, meets it, and rotates onward, leaving the moon behind.

A moon calendar, showing the appearance of the moon each day during one month. Although the dark part of the moon is not visible, it is shown here to point out that the moon does not really change in shape. Study the order and appearance of the four phases. How many days elapse between two *new moons*? Why are there not always exactly seven days between phases? Make a moon calendar of your own.

From observing the moon at the same time for several evenings, you have learned that the moon is not always in the same position. Each evening at the same hour, the moon is seen to have moved a distance to the east. Thus we realize that the moon travels *from west to east*. It moves in a nearly circular *orbit*, or path, around the earth, taking almost a month to complete each revolution. Because of this eastward movement, the moon "rises" about fifty minutes later each day.

Phases of the moon

Probably the most remarkable thing that you have observed from

Photographs of the moon, showing its phases (reading from top left to bottom right): The crescent moon one day after *new moon*; the crescent moon five days after new moon; the *first quarter*, seven days after new moon; the *full moon*, fourteen days after new moon; the *last quarter* as seen after twenty-one days; the waning moon on the twenty-eighth day, just a day before the next new moon. How can you tell from which side the sun is shining in each photograph? Remember that the first quarter appears on the *right-hand* side, and the last quarter on the *left-hand* side. (Mount Wilson and Palomar Observatories photos)

watching the moon and from making daily drawings on your moon calendar is that the shape of the part of the moon that we can see is continuously changing. Sometimes you can see the entire face of the moon; at other times you can see only crescents on the right or on the left-hand side

of it. From studying your moon calendar, you can see that in 29 days the first drawing that you made is repeated. During the month, you saw all the *phases* of the moon. What causes these changing phases of the moon?

SOMETHING TO DO

Obtain a ball such as a softball, volleyball, or basketball, and a bright flashlight. Darken your classroom. Does the ball have any light of its own? Imagine that the ball is the moon and that the flashlight is the sun. Shine the "sun" on the "moon." How much of the moon can be lighted at any one time?

Just as the ball has no light when it is held in a dark room, so the moon has no light of its own. The light of the moon is really light from the sun *reflected* by the moon's surface. As you can see, only one-half of the moon can be lighted at a time. However, we cannot always see all of this lighted half.

In seeing how the phases of the moon are caused, it will be necessary to move the "moon" in a circle around you, just as the moon moves in its orbit around the earth. First, hold the "moon" nearly between you and the "sun," but slightly higher than your head. What part of the "moon" is lighted? The side toward you is dark. This phase is called the *new moon.* Just after new moon, we can usually see a very thin crescent on the right side of the moon (see page 260).

Now move the "moon" slightly to your *left,* while you and the "sun" remain in the same places. Do you see a *crescent* on the right-hand side? Continue moving the "moon" to the left until it has gone *one-quarter* of the way around you. How much of the right side of the moon is lighted? When the right-hand half of the "moon" is lighted, we call it the *first quarter.* Why do you think we call it first quarter?

Now move the "moon" to the left until it has gone *halfway* around you. (Continue holding the ball slightly higher than your head so that your head is not directly between the "moon" and the "sun.") What shape is the "moon" now? How much of the lighted part can you see? Why do we call this phase *full moon?*

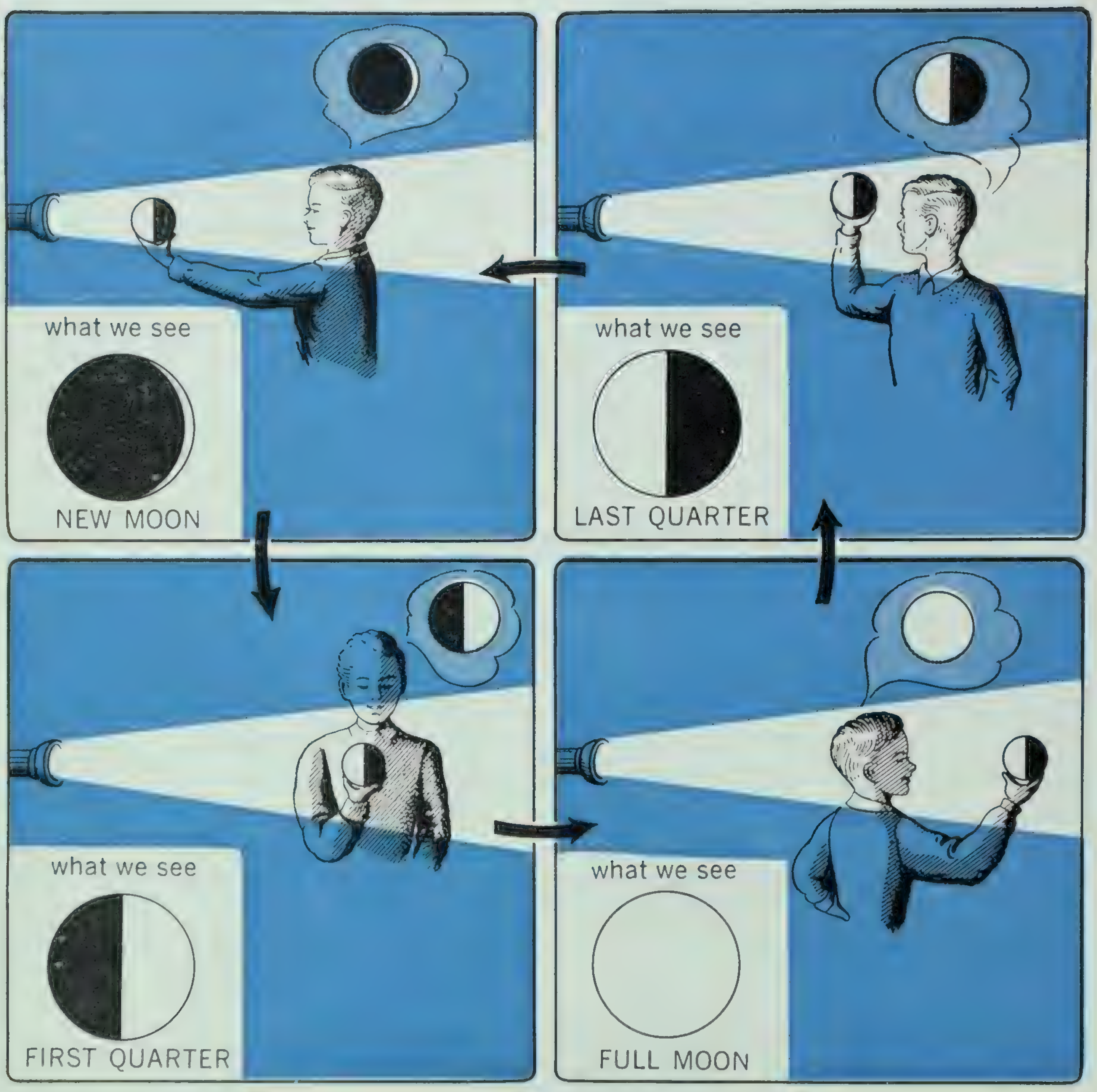
Again move the "moon" to the left until it has completed *three-quarters* of the circle. Which side of the "moon" is lighted now? When the left-hand half of the moon is lighted, we call it the *last quarter.* How can you tell the first quarter from the last quarter?

Again move the "moon" to the left until you have completed the circle. What phase takes place when the moon is in this position, almost between the earth and the sun?

The experiment that you have performed shows you what takes place as the moon makes its journey around the earth. As you have seen, the moon has four phases: new moon, first quarter, full moon, and last quarter. About seven days elapse between phases.

SOMETHING TO DO

1. Study the moon calendar that you have been making. Can you find the phases? On the correct dates, mark in the names of the phases.



Perform this experiment to find out how the moon's phases are formed. Follow the directions given on page 259. How can you tell the first quarter from the last quarter? At the full moon position you should not stand *directly* between the "sun" and the "moon." Why?

2. Study a large wall calendar on which the dates of the phases of the moon for other months are shown. What are the dates of the phases? How many days elapse between phases? Account for the fact that 8 days, instead of 7, sometimes elapse between two phases, bearing in mind that the phases are repeated every 29½ days.

An eclipse of the sun

Have you ever been fortunate enough to see an eclipse of the sun? During a *partial eclipse,* a large part of the sun is covered, making the sun appear crescent-shaped. During a *total eclipse,* the sun is almost completely darkened, and, as a result, the

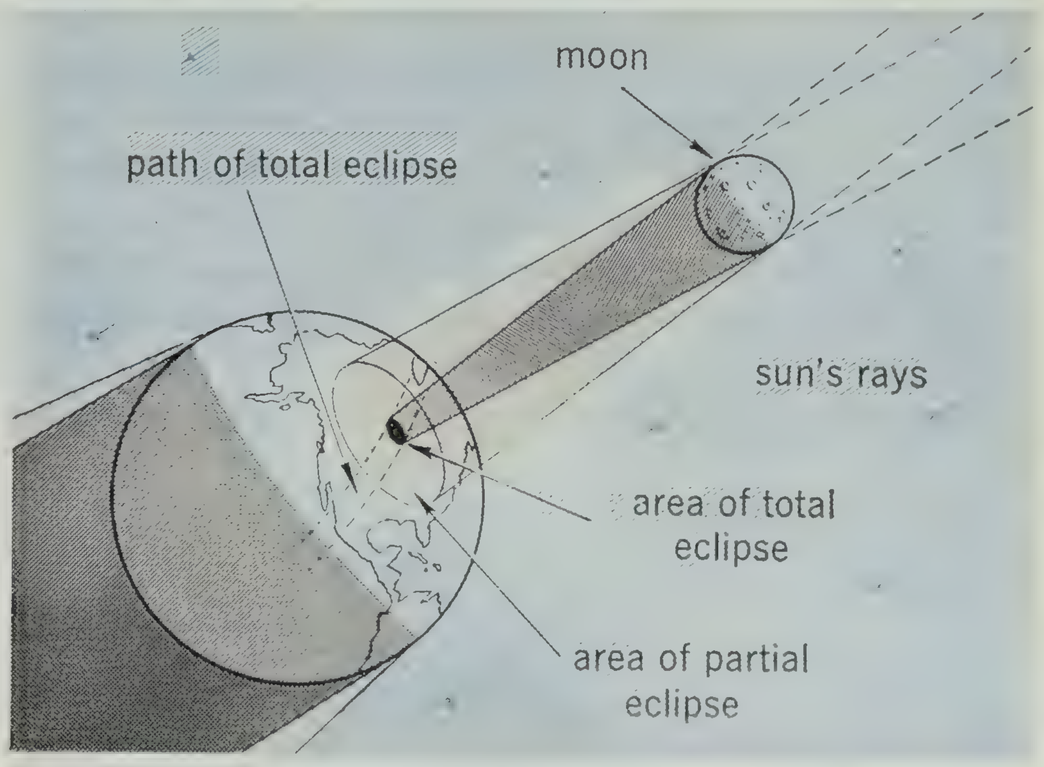
day becomes as dark as twilight. What causes an eclipse of the sun?

SOMETHING TO DO

Use a ball and flashlight to represent the moon and the sun. Hold the "moon" in a direct line between one eye and the "sun." Close the other eye. Can you see the "sun"? Move the "moon" slightly to one side. Describe the "sun." Slowly move the "moon" across between your eye and the "sun." What changes occurred in the shape of the "sun"?

A *total eclipse of the sun* can occur only when the moon passes directly between the earth and the sun. Each total eclipse can be seen from only a

A total eclipse of the sun. What is the round black area? What can we learn about the sun from this picture? (Mount Wilson and Palomar Observatories photo)



How an eclipse of the sun is caused. What would be seen from the area of total eclipse, and from the area of partial eclipse?

small part of the earth (see the illustrations on this page). During a total eclipse, the moon can be seen moving slowly across the sun, keeping the sun's light from reaching us. Soon, the entire sun is blackened out. Then the sun begins to appear again as a thin crescent, as the moon continues to move across it. Finally the entire sun can be seen again.

Eclipse of the moon

What would happen if the moon, on its orbit around the earth, passed through the earth's shadow?

SOMETHING TO DO

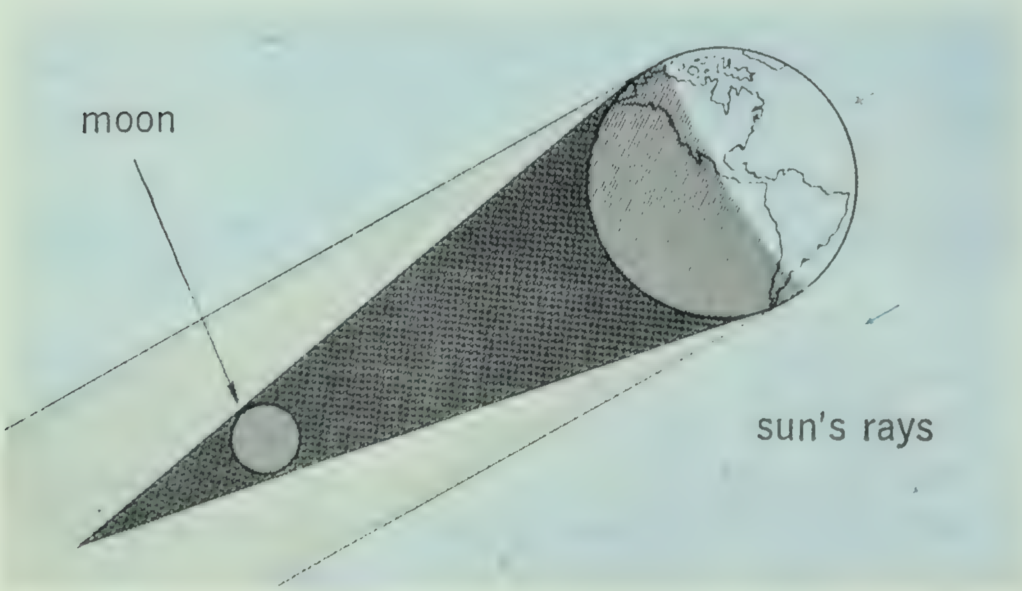
Use a ball and a flashlight for the moon and the sun. Hold the "moon" in the position of full moon, and move it so that it passes into the shadow of your head, which represents the earth. What happens to the "moon"? Why can an eclipse of the moon occur only at full moon?

An *eclipse of the moon* takes place when the sun, earth, and moon are in a straight line (see the illustration on this page). During an eclipse of the moon, the moon does not completely disappear, but becomes hazy in appearance. An eclipse of the moon can occur only at full moon because that is the only time when the moon is on the side of the earth opposite the sun.

Astronomers (scientists who study the stars, the moon, and the planets) are able to calculate the exact dates when eclipses of the sun and moon will occur. Eclipses are usually forecast in newspapers, and you can therefore watch for these interesting occurrences.

When looking at eclipses of the sun, protect your eyes by looking through glass darkened with lampblack. Prepare such a glass by holding a piece of glass just above a candle flame until it becomes black. If you prefer, look through several discarded photographic negatives.

Ancient people feared eclipses, and had many superstitions about them. With the development of scientific thinking, men began to look for natural causes to explain eclipses. Today, we know what causes eclipses, and instead of fearing them, we look forward to seeing these spectacular events. Scientists study eclipses to help them learn many things about the sun. Today, we have such accurate information about the movements of the earth and moon that eclipses can be forecast to the exact minute.



How an eclipse of the moon takes place. Try to find out from an astronomy book why eclipses do not occur every month.

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. Compare the distances to the
and in the time required for light fro
2. Compare the size of the moor
3. How can you find out wheth
to east? Why does it seem to go from
ing?
4. Name and draw the four phas
order.
5. Describe an experiment that
ing phases are caused.
6. Make drawings to show the
eclipse of the sun and an eclipse of th

THE SOLAR SYSTEM

Time for One Revolution	Satellites (moons)
88 days	0
225 days	0
365¼ days	1
687 days	2
11.9 years	12
29.5 years	9, and 3 rings
84 years	5
165 years	2
248 years	unknown, probably none

THE SOLAR SYSTEM — THE SUN'S FA

The earth is not the only sphere revolving around the sun. The sun has a group of nine *planets,* including the earth. Each planet travels around the sun in its own *orbit,* or path. The *solar system* is the name given to the sun and its family of planets.

Besides the earth, five planets were known to the early Greeks and Romans. Two of them, *Mercury* and *Venus,* are closer to the sun than we are; the others – *Mars, Jupiter,* and *Saturn*—are farther from the sun. With the invention and improvement of telescopes, three more distant planets – *Uranus, Neptune,* and *Pluto* – have been discovered, the last as recently as 1930.

Like the earth, the planets are all spherical in shape. They vary greatly in size, some being smaller than the earth, and some being much larger. (See the illustration on page 264.)

Th
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30
di*ne,* which you can obtain in your
alchool or community library.
di
ca You can tell planets from stars by
size fact that planets do not seem to
quvinkle, as stars appear to do. Venus
con be seen only during the evening
sund early morning. When visible, it
M the brightest object in the sky,
ev her than the sun and the moon. In
me evening, it can be seen earlier than
rey night star, and is often called the
ar*vening Star.* Why is this not a suit-
ble name for Venus? Jupiter also is
ovrighter than any night star. Mars
bepears to be very red, and is there-
re)re easily identified when it is visible
as the night sky.

Eclipse of the moon

What would happen if the moo on its orbit around the earth, passe through the earth's shadow?

SOMETHING TO DO

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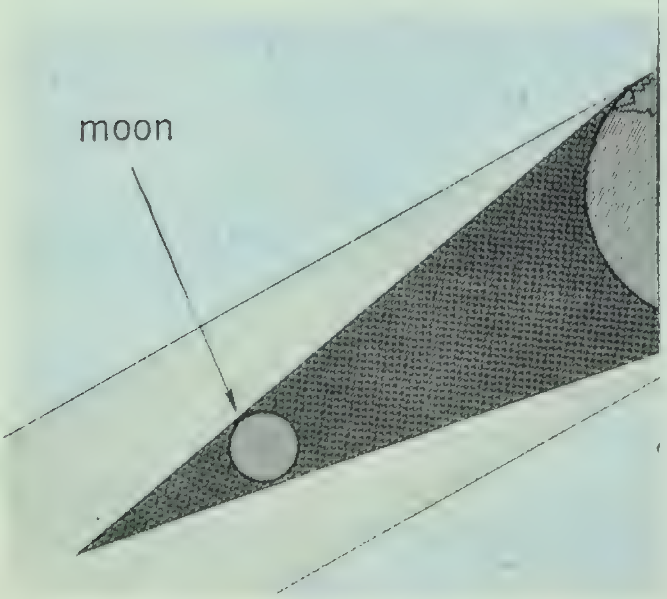
An *eclipse of the moon* takes plac when the sun, earth, and moon are i a straight line (see the illustration o this page). During an eclipse of th moon, the moon does not completel disappear, but becomes hazy in ap pearance. An eclipse of the moon ca occur only at full moon because tha is the only time when the moon is o the side of the earth opposite the sun *Astronomers* (scientists who stud the stars, the moon, and the planets



← The illustration at the left shows a comparison between the sizes of the planets and the sun. Jupiter is larger than all the other planets combined. Which three planets are the smallest? Where does the earth rank in size among the planets?

The earth is not the only planet with a moon revolving around it. Three of them have no moons, but some of them have many. Jupiter has twelve, and Saturn has, in addition to its nine moons, three broad, thin rings which are composed of billions of small particles.

You recall that the earth rotates on its axis every twenty-four hours. Similarly, the other planets rotate, most of them much more rapidly than the earth.

SOMETHING TO DO

1. Study the illustration on this page and the table on page 265, which show and tell you many facts about the planets. Which planets are most like the earth in size? Which is the largest planet? Which four are much closer to the sun than the others? Which ones have no moons?

2. Hang a wire or strong cord joining opposite corners of the classroom. From it, hang, in order, the following spheres to represent the planets: Mercury, a large bead; Venus and the Earth, golfballs; Mars, a large marble; Jupiter, a basketball; Saturn, a volleyball, on which you should attach three cardboard rings; Uranus and Neptune, softballs; Pluto, a large marble. Using the table on page 265, distribute them to show the comparative distances among them. Of course, they will be much too crowded. Using spheres of the sizes

TABLE OF FACTS ABOUT THE SOLAR SYSTEM

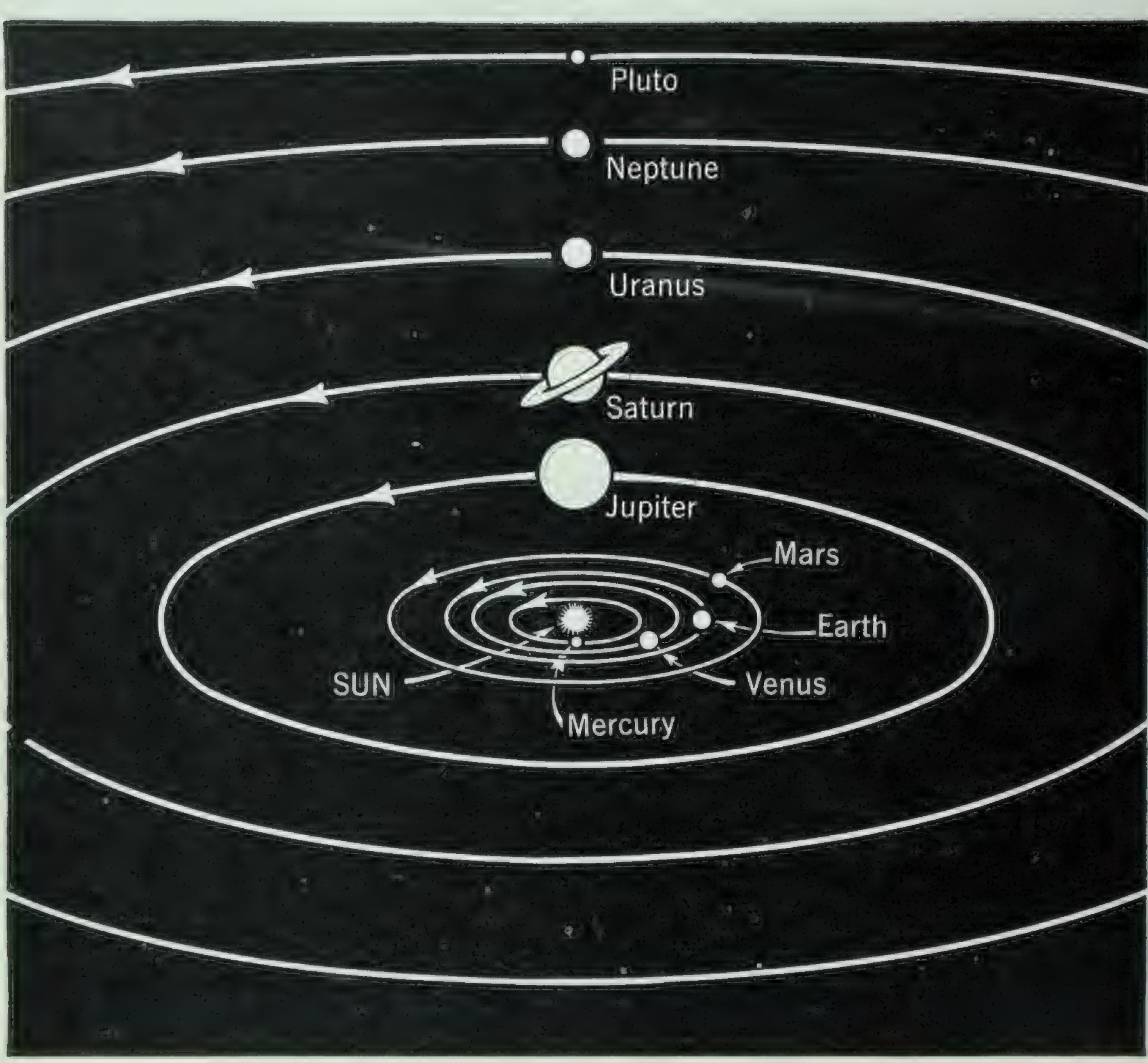
Names	Distance from Sun (in millions of miles)	Diameter	Time for One Revolution	Satellites (moons)
Sun		860,000		
Planets				
1. Mercury	36	3000	88 days	0
2. Venus	67	7500	225 days	0
3. Earth	93	8000	365¼ days	1
4. Mars	140	4200	687 days	2
5. Jupiter	480	88,000	11.9 years	12
6. Saturn	890	76,000	29.5 years	9, and 3 rings
7. Uranus	1780	32,000	84 years	5
8. Neptune	2800	31,000	165 years	2
9. Pluto	3700	3500	248 years	unknown, probably none

shown, you would have to have a string over seven miles long to allow you to spread the spheres out properly!

3. Watch for stories about the planets in other science books. You may be interested in learning whether humans or other forms of life could live on the other planets. Most scientists think that conditions such as high and low temperatures and lack of suitable air make life on most other planets impossible.

4. Five of the planets are bright enough to be seen in the night sky without the aid of a telescope. Because their positions in the sky are different each year, you must ask an *astronomer* to locate them for you, or consult a *star map* for the present month. Such a map is shown every month in *Nature Magazine,* which you can obtain in your school or community library.

You can tell planets from stars by the fact that planets do not seem to twinkle, as stars appear to do. Venus can be seen only during the evening and early morning. When visible, it is the brightest object in the sky, other than the sun and the moon. In the evening, it can be seen earlier than any night star, and is often called the *Evening Star.* Why is this not a suitable name for Venus? Jupiter also is brighter than any night star. Mars appears to be very red, and is therefore easily identified when it is visible in the night sky.

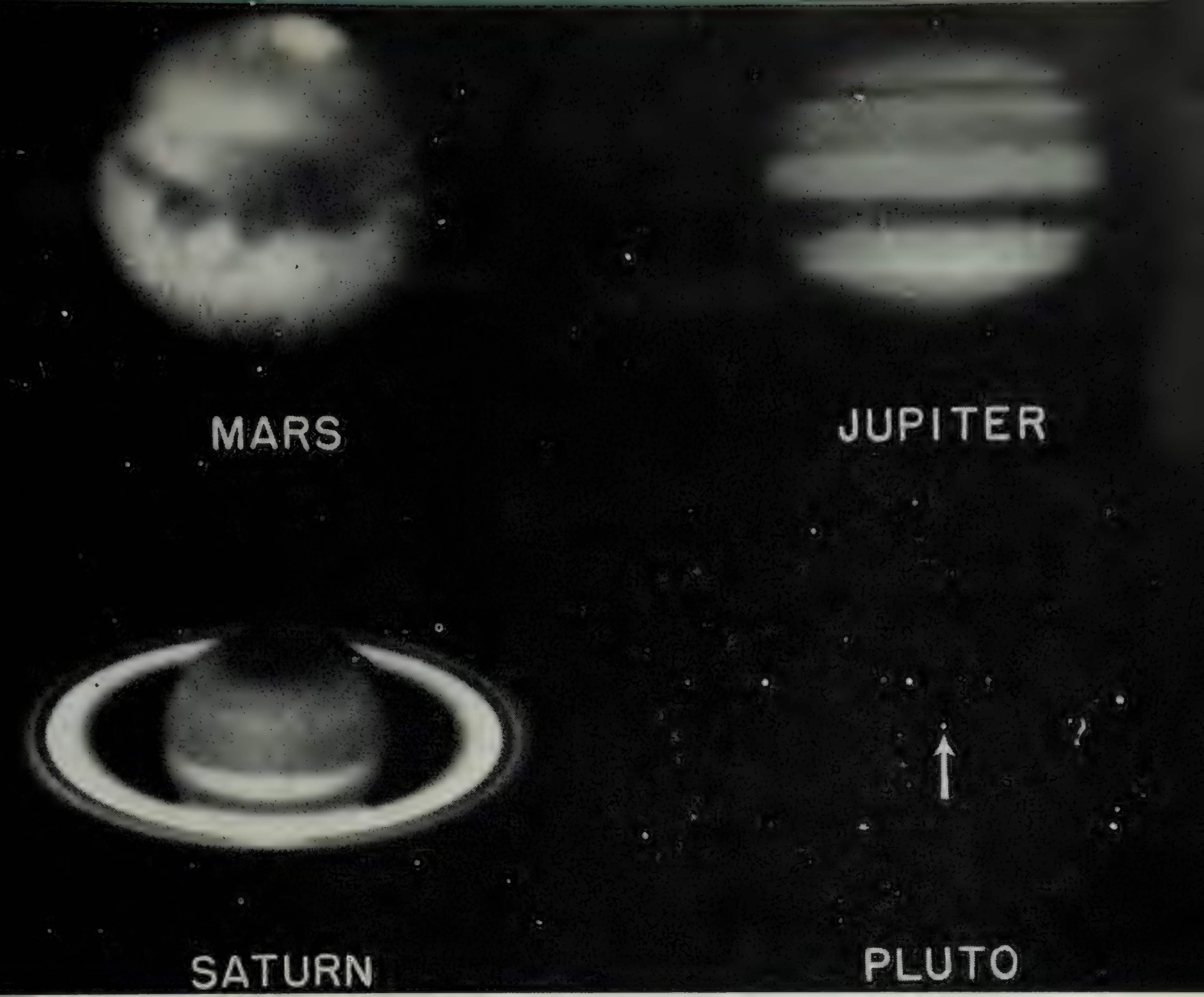


The orbits of the planets. In a drawing, it is impossible to show the sizes of the planets in proportion to the vast distances between their orbits, because all of them would be too small to be seen. Check the drawing on page 264 for a comparison of the sizes of the planets and the sun. See the table on page 265 for the distances of the orbits from the sun. What four planets are most closely grouped?

Meteors and comets

Have you ever seen a "falling star"? Those bright flashes of light are not stars; they are tiny pieces of rock falling toward the earth from the great space beyond our atmosphere. As they fall rapidly toward the earth, the *friction* caused by rushing through the air makes them become hot, and they start to burn. These tiny *meteors,* as they are properly named, usually burn out or break up before they reach the earth. Occasionally a larger one, called a *meteorite,* strikes the earth and buries itself in the ground.

Within the solar system are a number of *comets.* A comet has a bright head resembling a star, and



Photographs of four planets. As you can see, Mars has a prominent white area, which may be a polar ice-cap. How can the astronomer identify Jupiter and Saturn? Give two reasons why Pluto appears so small in this group of photographs. The other white spots shown near Pluto in the photograph are stars, which are much larger and thousands of times as far away as Pluto. (Mount Wilson and Palomar Observatories photo)

a long, glowing tail. Comets travel in great oval-shaped orbits within the solar system. Most comets take many years to complete their orbits, but they return to our part of the solar system after fixed periods of time. The best known comet, *Halley's comet*, has appeared in our part of the solar system every seventy-six years, and should appear again in 1986. When comets appear, they are often visible for many nights. Ask your grandparents if they remember seeing Halley's comet in 1910 (see page 268). Because comets are made up mostly of gaseous materials, there is no need to fear the chance of the earth colliding with them. Long ago, people greatly feared these heavenly spectacles. Modern science drives out such fears and superstitions with facts. In 1910, scientists predicted that the earth would pass through the tail of Halley's comet. It did so, unknown to most people, and with no harmful effects.

A photograph of Halley's comet, taken in 1910 through a small telescope. Why cannot this comet be seen tonight? (Mount Wilson and Palomar Observatories photo)

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. In what ways are the other planets similar to the earth?
2. Which planets are closer to the sun than the earth is?
3. Which planets appear brightest in the sky?
4. What do you consider the most interesting feature of Saturn?
5. What planets are smaller than the earth?
6. Give two reasons why distant planets take longer to revolve around the sun than do planets close to the sun.
7. State two ways in which meteors differ from comets.
8. What is a meteorite?

OUT AMONG THE STARS

As you know, man has been interested in the stars for thousands of years. Long ago, people noticed that each year at the same time the stars were in the same positions in the sky. They noticed that some stars were much brighter than others, and they named most of the bright stars. They also observed, as you too can see by looking at the stars any clear night, that many of the stars seem to be clustered in groups. These clusters of stars, called *constellations,* were imagined to be in the forms of people, animals, and other objects, and were given names.

The *Big Dipper,* in the northern sky, is one of the easiest constellations to find. In olden times, the Big Dipper was called the *Great Bear.* It is much easier to imagine it as a dipper than a bear.

It is easy to learn to use the Pointers of the Big Dipper to locate the *North Star.* Find the two stars in the Big Dipper that are farthest from the handle. Now imagine that you can draw a straight line out from these

How to use the Big Dipper to find the North Star. Why do we consider the North Star to be the most important star in the night sky?

Pointers. At a point on this line about five times as far as the distance between the two Pointers, you will find the North Star. The North Star is also the end of the handle of the *Little Dipper*, or, as it was formerly called, the *Little Bear*. Only on very clear nights are we able to see the Little Dipper clearly.

Of all the stars in the night sky, the North Star is the most important. Because it always remains in the same position, it is useful for telling in what direction you are travelling at night.

Besides the Big Dipper and Little Dipper, two other constellations are visible in the north sky on any clear night. On the opposite side of the North Star from the Big Dipper is a group of five fairly bright stars in the form of a large W. The name given to this constellation is *Cassiopeia*,

Orion is usually considered to be the most beautiful constellation. Find Orion's belt, sword, club, lion's skin, and the two bright stars, Betelgeuse and Rigel.

which the ancients imagined to be a *queen*. The long, winding row of stars near the Dippers forms *Draco*, the *dragon*. These two constellations, the queen and the dragon, have kept the names given to them by the ancients. Most other constellations have also kept the names given to them long ago.

The most spectacular of all constellations, *Orion*, the *hunter*, can be seen in the south-eastern sky in early evening in January and February. Three bright stars in a straight line form Orion's belt. Above the belt is a very bright red star, *Betelgeuse*, which is many millions of times as big as the sun. Betelgeuse marks Orion's right shoulder. Below the belt is another very bright star, *Rigel*, which marks Orion's left foot. Several stars of lesser magnitude complete this beautiful winter constellation. To the left of Orion, almost in line with the belt, can be seen the brightest star in the night sky, *Sirius*, the *dog-star*.

By watching Orion from time to time during a clear evening, you can observe that it seems to rise, move to the west during the night, and set beyond the western horizon. With each passing hour, some stars disappear in the west and others rise in the east. You will remember that the sun's apparent westward movement is caused by the fact that the earth rotates toward the east. Similarly, the eastward rotation of the earth presents to our view new groups of stars, while other groups seem to move westward and disappear from view in the west. This is the case with all the constellations of the southern sky.

On the other hand, many of the constellations in the northern sky, including the Dippers, can be seen throughout the night. There is a good reason for this. The earth's axis points toward the North Star, and continues to do so as the earth rotates. Thus, by looking to the north at any time during a clear night, we can see the North Star and the constellations near it until the brightness of daylight outshines their dim light, and they disappear from view. Of course, they are still there throughout the day, but we cannot see the faint light coming from them.

Perhaps you have wondered why we cannot see Orion during the summer. You will recall that the earth revolves around the sun once a year. As the earth moves along, new parts of the starry universe become visible from month to month. At the end of six months, the earth is on the other side of the sun, and entirely different groups of constellations can be seen in the southern sky at night. However, because the earth's axis continues to point to the North Star, we can see many of the northern constellations at any time of the year, just as we can see them at any time of night.

SOMETHING TO DO

There is a great deal of enjoyment and satisfaction to be gained from learning to recognize the more familiar constellations in the night sky. Some of the

brightest stars and most interesting constellations are visible during the winter months.

A map of the constellations that are visible in early evening in February is shown in the illustration on page 272. Find the points of the compass on the map. To use the map, you must hold it above your head with the map facing down, and turn it so that the compass points are in their proper directions. Now the map is a picture of the night sky. If you can imagine that the map is shaped like the inside of an umbrella or bowl held over your head, you will see that the map becomes similar to the sky. Each constellation shown on the map is in the same position in the sky.

Take the map outside on a clear night, preferably when the moon is not in sight. Go some distance away from houses and street lights, on a hill, if possible. A flashlight will be useful for locating constellations on your star map. Can you find the Big Dipper, the North Star, the Little Dipper, Cassiopeia, and Draco? Find Orion in the south. Sirius is easy to find because of its brightness. Look high in the western sky for the *Pleiades*, or *Seven Sisters*, a group of seven stars closely crowded together. You will probably be able to see only six of the seven stars in this constellation. Now you can find the other constellations shown.

On a clear night, you will see very many stars not shown on the map.

2. Using some black cardboard and a shoe box, make yourself a star peep-box. Cut a slit in one end of the box and a larger opening in the other end. Cut black cards that will fit over the open end. Use one card for each constellation and use a pin and a needle to punch *very small* and *slightly larger* holes for the stars in the constellation. *Make the holes as small as possible.* Put the card in place and look through the peep-hole toward a light.

3. A useful star map can be made by pasting *very small* pieces of silver paper, to form the shapes of the constellations, on the inside of an old black umbrella from which some of the ribs have been removed.

4. If you have a lantern slide or film strip projector, you can easily make slides of black paper with tiny holes to represent stars in various constellations. Project these constellations on the ceiling of your darkened classroom.

5. Consult reference books to find out why the constellations were given the names by which we identify them.

6. In science books and magazines, find star maps for other months, and use them to locate and identify other constellations as they appear from month to month.

How big are the stars?

Do you remember learning that the sun is a star? Although the sun seems very large when compared with the earth, it is not one of the largest stars. There are many stars much larger than the sun. As you know, Betelgeuse, in the constellation Orion, is many million times as big as the sun. For all its size, Betelgeuse is not the largest star in the sky. When you realize how large some of the stars are, you will begin to understand how far away they must be when they appear to us to be so small.

Distances to the stars

When you learned that the sun is 93,000,000 miles away, you probably

A winter star map. To use this star map, follow carefully the directions given on page 271. This map shows you the locations of the constellations at the following times: mid-January, 10 P.M.; early February, 9 P.M.; mid-February, 8 P.M.; late February, 7 P.M.

thought this a vast distance. Compared with the distances to the stars, however, the sun is very close to us. In fact, the nearest star, other than the sun, is about 250,000 times as far away as the sun! By recalling that the

This star map shows the constellations as they are seen a month later than on the map on the opposite page. Use this map in early March at 9 p.m.; mid-March at 8 p.m.; late March at 7 p.m. Notice the changes that have occurred in one month.

distance to the sun is about 93,000,000 miles, you could check for yourself the approximate distance, in miles, to the next nearest star. You would find this distance to be about 24,000,000,000,000 (twenty-four trillion) miles!

Distances to the stars are so great that astronomers do not measure them in miles. Instead, they measure these distances in terms of units based on the length of time it takes light to come from them to the earth. You

A galaxy as seen through a telescope.

have learned that light comes to us from the sun in 8½ minutes, and from the moon in only 1¼ seconds. Does it surprise you to learn that the light from the nearest star other than the sun takes 4 years to reach us? We say that the nearest star is *4 light-years* away. *A light-year is the distance that light travels in one year.* We know that a ray of light travels 186,000 miles per second. How would you find the number of miles in one light-year?

Most of the stars you see at night are *many* light-years away. Some are hundreds, others thousands of light-years away. When we look at a star in the sky, we may be seeing light which left it hundreds of years ago, and which for all that time has been travelling toward us at the amazing speed of 186,000 miles per second. When we realize the great distances to the stars, we gain some idea of the vastness of the universe.

Have you ever seen the *Milky Way*, the great band of faint stars stretching across the night sky? Many of the stars in the Milky Way are hundreds, and others thousands, of light-years distant from the earth. A photograph of a small part of the Milky Way may be seen on page 241.

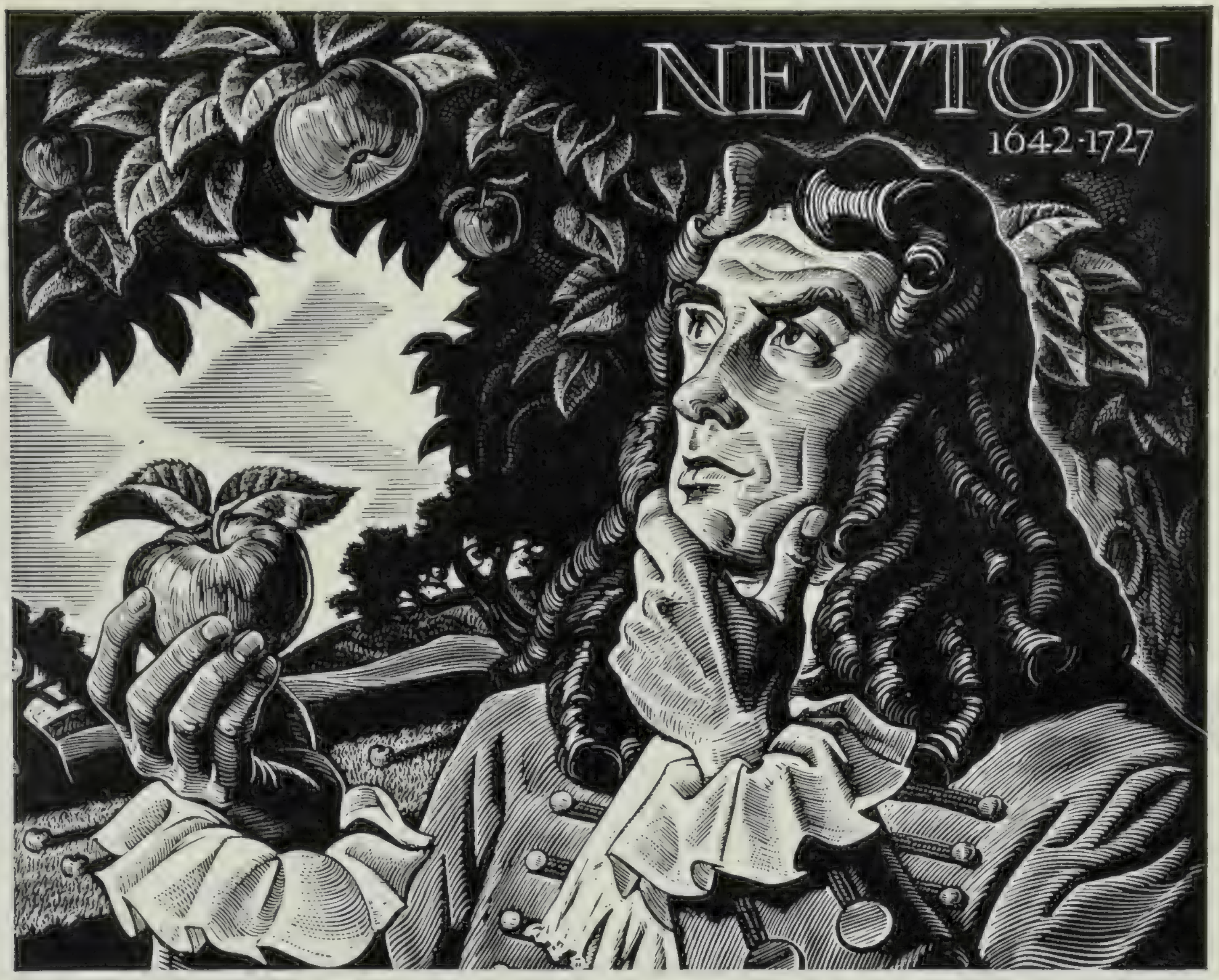
One night recently, a young scientist in Chicago was studying a small section of the sky through a powerful telescope. As he watched, he saw a faint star begin to glow very brightly. Through the telescope he took a photograph of this unusual happening, thought to be the result of a great explosion in the star. When the distance to the star was calculated, it was learned that it was a thousand light-years away. The sudden glowing of the star really took place a thousand years ago! The young scientist had actually seen and photographed an event a thousand years after it happened.

How many stars are there?

When you study the sky on a clear night, you may see 2000 to 3000 stars. You can see only the brightest of the billions of stars that exist. Scientists do not know how many stars there are, or how far away the most distant ones are. As more powerful telescopes are developed, each of them reveals to man's sight more stars, and more distant ones.

In recent years, scientists have invented radio-telescopes, which record radio waves given off by stars. These new instruments will probably be of great assistance in helping the astronomer to learn more about the size and number of stars, and the distance to them.

By observation, modern scientists have learned that our sun and solar system, along with millions of stars, form one great cluster of stars called



Isaac Newton, an English mathematician, first discovered why the planets stay in their orbits. It is said that one day as he sat studying under an apple tree, an apple fell on his head. He wondered why it fell *down* instead of in some other direction, and finally concluded that each object has a force, called gravity, that attracts other objects toward it. The opposite forces of gravity and the forward motion of each planet balance each other, so the planet neither is pulled into the sun nor rushes off into space. Newton also discovered the laws upon which the successful flight of modern rockets depends. (International Nickel Company of Canada)

a *galaxy*. They also know that beyond our galaxy are many galaxies, each made up of millions more stars. How many galaxies exist is a problem not yet solved by astronomers. Numbering the stars and calculating the distances in the vast universe is apparently beyond man's present ability to accomplish or even to imagine. With all the millions of stars in the sky, all moving along at great rates of speed, you probably wonder if stars frequently bump together. For all their great numbers, the stars are not crowded in the sky. Do you recall that the nearest star is 250,000 times as far away as the sun? The other stars are also very widely scattered, so that there is little chance that they will collide. One scientist has said that *the stars are no more crowded than five bees would be flying anywhere over Canada!*

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. Why don't we see the same stars in the southern sky throughout the year?
2. Why do the southern stars seem to rise and set?
3. Why are we able to see some of the northern constellations throughout the night and throughout the year?
4. During early evening in February, where would you find the following constellations: Cassiopeia, the Pleiades, the Big Dipper, Orion, Pegasus?
5. How can you use the Big Dipper in locating the North Star?
6. How does the sun compare in size with the other stars?
7. What is a light-year? What use does the astronomer make of this unit of measurement?

WHY DO WE STUDY ASTRONOMY?

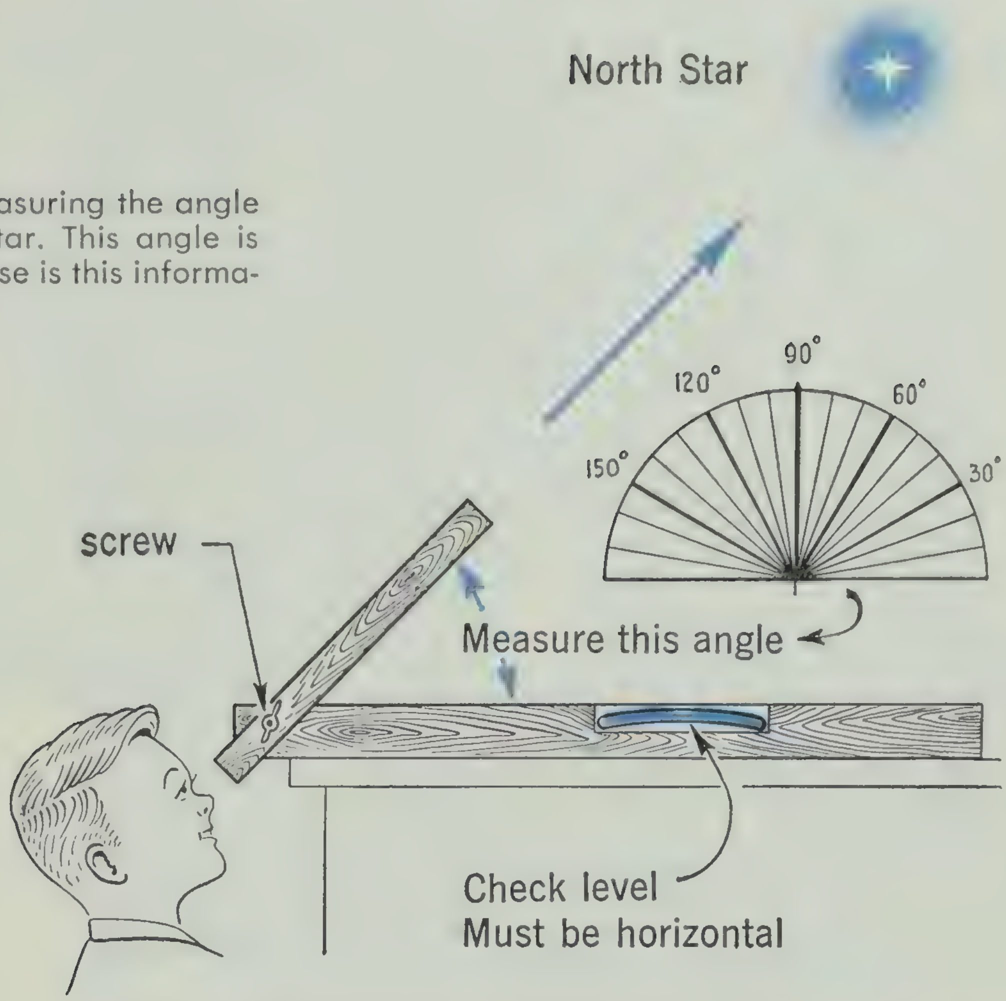
Astronomy, the study of the heavens, is one of the most interesting and challenging branches of science. When Mr. Kennedy's class was reviewing what they had learned in this field of science, their teacher reminded them that one of their reasons for beginning this study was to find out how these other objects in our universe are useful to us.

"We have learned that we get light and heat from the sun," said Stella Veres. "Without sunlight we could not exist. Plants could not produce starch without sunlight. Without heat from the sun, our earth would be a cold, dead world."

"We also use the sun and stars in navigation," added Ben Rosen. "In daytime, if you know what time it is, you can tell directions from the sun's position. At night, if you can find the North Star, which is visible in the sky every clear night, it is easy to figure out all the directions."

"It is possible to use the North Star to locate your *latitude,* that is, your position north of the equator," said Mr. Kennedy. "To help locate places on the earth, geographers have located *parallels of latitude.* There are ninety of these south of the equator, and ninety between the equator and the North Pole. Each parallel of latitude is an imaginary line circling the globe, parallel to the equator. The equator is called 0° (0 degrees); as you go north, you cross the imaginary parallels of latitude called 1°N, 2°N, and so on. The lines of latitude are marked on many maps."

The number of degrees in the angle of the North Star above the earth's surface at any place in the northern hemisphere is the same as the degree of latitude for that place.



A home-made device for measuring the angle of elevation of the North Star. This angle is also your latitude. Of what use is this information?

SOMETHING TO DO

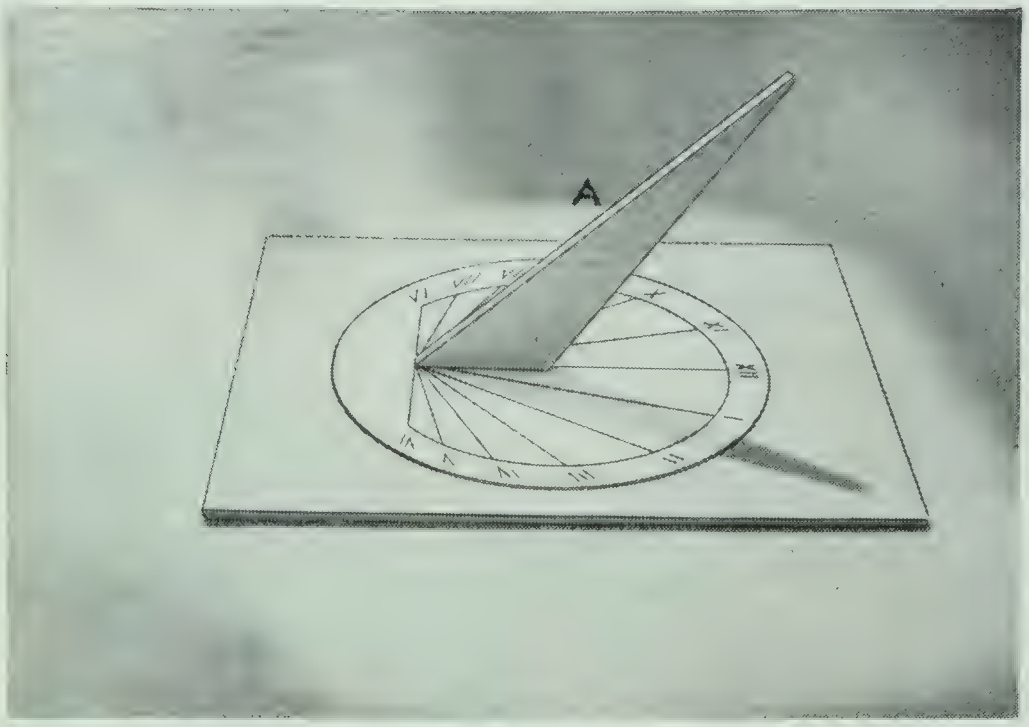
Use a spirit level and a protractor to find the angle of the North Star above the earth at your community. (See the illustration on this page.) This angle should tell you your latitude. Check an atlas or large globe to see how accurate your measurement was.

On board a ship at sea, the captain uses a *sextant,* which works very much like the apparatus you used to find your latitude. With the sextant, the captain can determine accurately the latitude of his position at sea.

Time from the sun and moon

What evidence can you produce to indicate that time on earth is measured by the movements of the earth and moon? What, for example, is a *year?* Is it not merely the length of time that the earth requires to revolve once around the sun? A *day* is the length of time that it takes the earth to make one complete rotation on its axis.

The day and the year are two of the oldest measures of time that have been evident to man. But early people needed some other way of keeping track of the many days in a year, and looked in the sky for another regular means of recording time. They noticed that the full moon reappeared about every 30 days. You already know that the phases of the moon are repeated every 29½ days. The ancients called the length of time between full moons a *monath.* Have you



A home-made sundial. The angle at the base of the longer edge (A) of the indicator should be the same as your latitude. The shadow of this edge marks the approximate time, if the sundial is situated so that the indicator runs due north and south. At what time was this photograph taken? (K. Nicholls photo)

ever heard of North American Indians referring to an event as occurring "several *moons* ago"? What unit of time has been obtained from this ancient measure? Notice the similarity of the words *moon, monath,* and *month.* How do our months differ from those used by the ancients? Why does the length of the moon's revolution around the earth not serve as a good unit for recording time?

The apparent movement of the sun, caused by the rotation of the earth, helps us keep track of time during the day. If you are on a hike and are not carrying a watch, how can you tell when it is noon? A *sundial* is a useful device for telling time from the position of the sun.

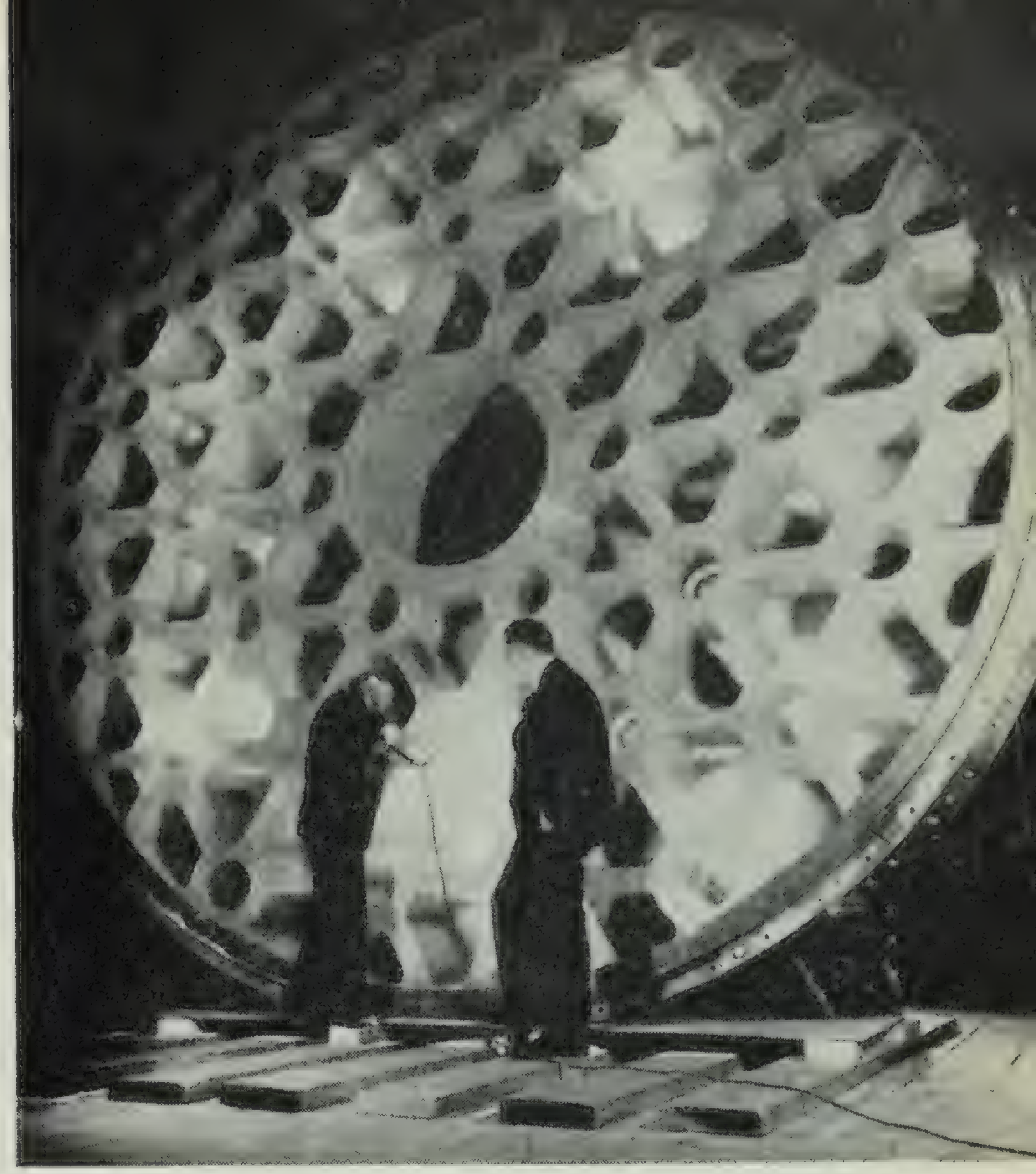
SOMETHING TO DO

Make a sundial for your garden, or make a simple sundial by driving a stick into a level piece of ground. Notice how the shadows move around during the day. Mark the positions of the shadows each hour. Your sun clock is now ready for use. Why is a mechanical clock better than your sundial?

The origin of the earth

One of the main reasons why astronomers try to learn new facts about the universe is that the more we discover about the heavens, the more we may be able to learn about our own earth – its place in space, its origin, and its possible destiny in the distant future.

Scientist have from time to time suggested various explanations of how the earth was formed. The theory most widely accepted at present says that at one time there were no stars, but only clouds of gas and dust drifting in space. Slowly the bits of matter were attracted to each other by the force of gravity. As the newly-formed clusters became larger they began to spin and heat up. At last they became stars. It is thought that the cluster from which the solar system was



The most important part of a reflecting telescope is a finely polished, concave mirror to focus the light rays that strike it. This picture shows the back of the 200-inch glass mirror used in the world's largest telescope on Mount Palomar, in California. The network of glass on the back strengthens the huge mirror, which weighs over 14 tons. This mirror gathers over 500,000 times as much light as a human eye. (Corning Glass Works photo)

formed became a flat, glowing disk. The centre of it became our sun. Other lumps formed in the disk and eventually became the planets. Gradually the earth cooled to its present form.

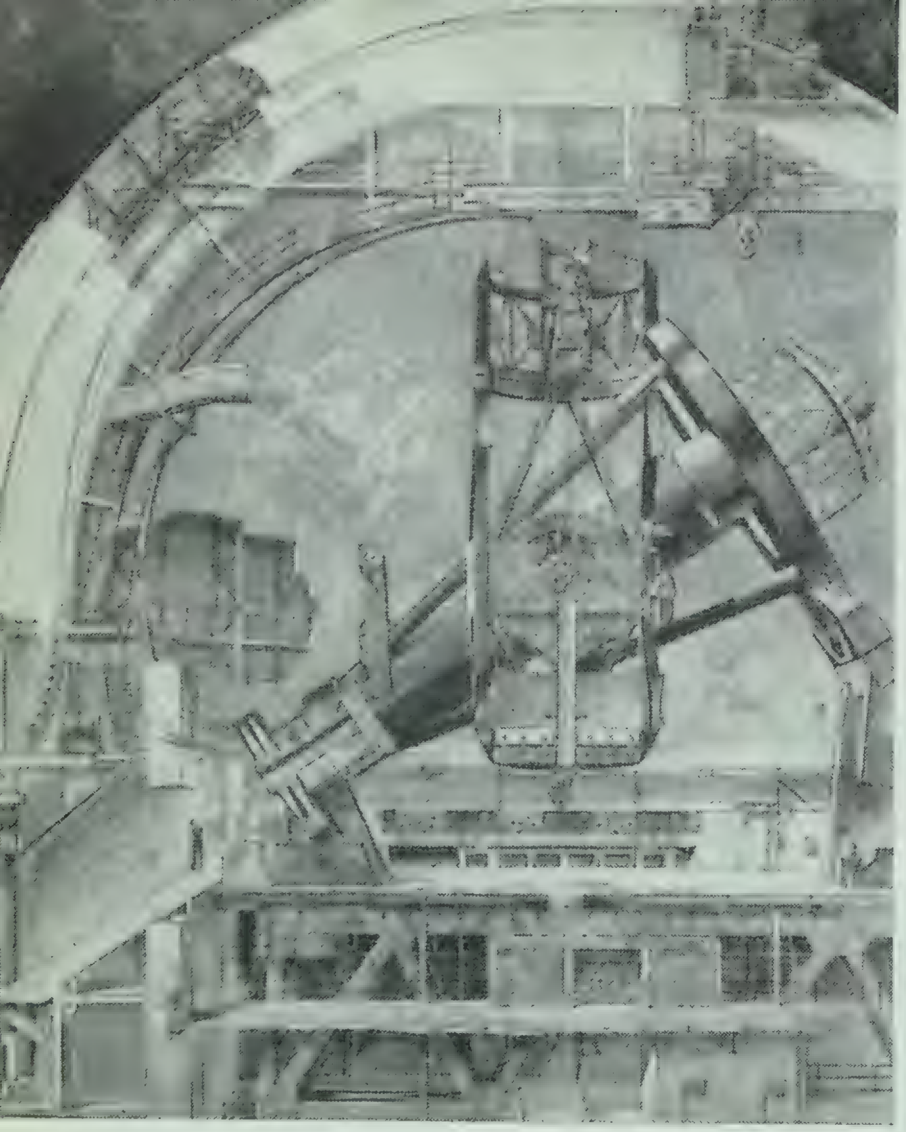
It should be remembered that this is only a theory about how the earth was formed. By studying the various kinds of stars, astronomers may some day learn more about how the sun, the planets, and the many distant stars were formed.

It is not known whether other stars have their own families of planets revolving around them, as the planets of our solar system revolve about the sun. If, in the future, it is found that other stars do have planets, we may learn from them more about the origin of our own solar system.

Recent discoveries

With the aid of modern instruments such as the giant Palomar telescope, scientists in recent years have learned much new information about the universe. As you know, they have found that all the stars we see each night form a huge galaxy. Beyond our galaxy are countless other galaxies far out in space. So numerous are they that over three hundred have been counted in the small part of the sky marked off by the four stars in the cup of the Big Dipper!

Within our own galaxy are numerous white clouds of dust and gas.



The 200-inch reflecting telescope, in which the large mirror shown on page 279 is used to collect light from stars. Compare the size of the telescope with the man at the left. The lighter drawings in the background show that the telescope can be turned in various directions. (Mount Wilson and Palomar Observatories)

They are called *nebulae* and are thought to contain *cosmic dust,* which is the material from which planets and stars may have been formed.

Stars of many kinds

When we look casually at the stars, they all seem to be dots of white light against the black expanse of space. But if you will look more carefully, you will see that some appear red, others blue, orange, and yellow, and white. In recent years scientists have learned to determine the age of stars by their colors.

The newest, or youngest, of the large stars are the *blue-white stars,* which may burn at temperatures of over 100,000° F. Many of these dwarf stars are no larger than the earth. *Yellow stars,* like our sun, are cooler than the blue-white giants. The *red giants* are probably the largest and brightest of all, but are cooler than stars of other colors. Some of the red giants are thousands of times as big as the sun. Another group of stars are the *white dwarfs.* Although they are small, they are very hot, and glow with an intense white light.

The stars that we call white dwarfs have one very unusual feature. The particles of material in them are packed so tightly that if a cupful of it could be brought to earth, it would weigh thousands of tons!

SOMETHING TO DO

Most of the stars that you can see at night are blue-white and yellow stars. However, several of our brightest stars are red giants. Look for these red giants: Betelgeuse, in the constellation Orion; Aldebaran, in Taurus; and Capella, in Auriga. You can locate these bright stars in the star maps on pages 272 and 273, but you should also look for them and see their red color in the night sky. Try to locate other red stars as well as some blue-white and yellow ones.

If you had an opportunity to see a piece of iron heated in a furnace or by a welding torch, you would see that the order of colors as the metal became hotter was the same as the order of the colors of a star. At first it becomes red; as it gets hotter it changes to orange, then to yellow, until finally it becomes white hot.

The life of a star

Based on what they have learned about the size and temperatures of the stars, astronomers think that a star goes through several stages. First it "burns" as a blue-white giant. When it has used up about 15 per cent of its fuel, it becomes much larger and cooler, and earns the name of red giant. It is thought that in its final stage it becomes a white dwarf, a small, compact star. Some stars explode when most of their fuel is gone; such an exploding star is called a *nova*.

Scientists think that the total life of a star is about 50,000,000,000 years. Our sun is probably still a young star, perhaps about 5,000,000,000 years old, or about the same age as the earth.

The earth's destiny

In the timetable of the universe, the earth is very young. Unless some unlikely disaster occurs, the earth should last as long as the sun. Scientists think that the sun should remain more or less the same for at least 3,000,000,000 years, a very long time indeed. Then, if the sun follows the same pattern as other stars, it likely will slowly become a red giant many times its present size. Eventually, perhaps 40,000,000,000 years from now, the sun will likely cease to shine, and the solar system will become dark and cold.

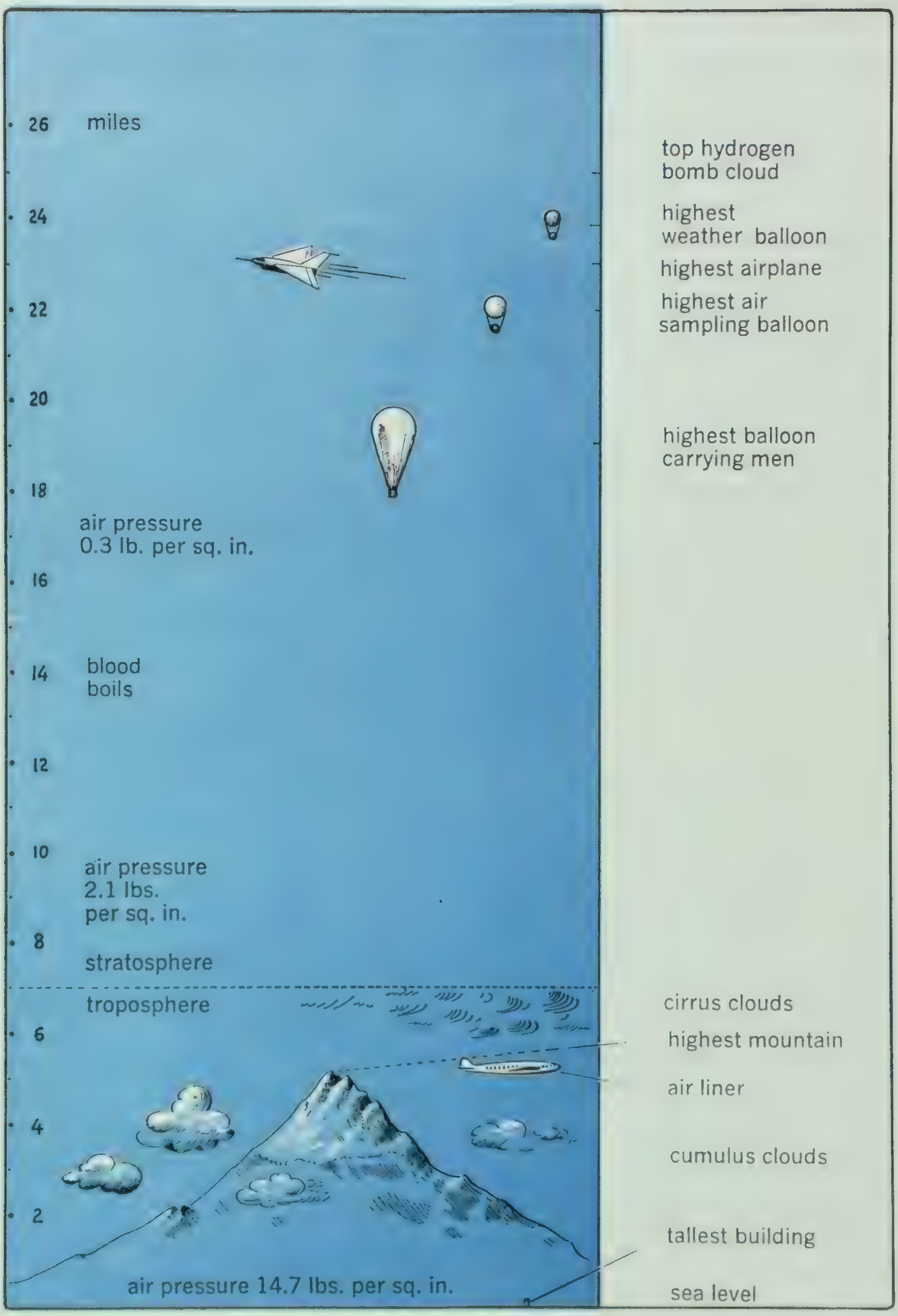
Looking to the future

We have learned a number of ways in which the sun, moon, and stars are useful to us. However, probably the chief reason for studying the objects beyond our earth is to satisfy man's curiosity. Man has always looked to the stars with wonder. Today we build larger and still larger telescopes to probe into the unknown, hoping to answer the many questions we ask about these worlds beyond our reach. As long as man has that desirable scientific attitude, the spirit of inquiry, we shall look out from the earth, and attempt to solve the many problems as yet unanswered.

Here is a question that astronomers are often asked: "Is there any life on Mars?" Although some photographs of Mars have shown green areas, suggesting plant life, no scientist has seen the planet clearly enough to give a final answer to this interesting question. Most scientists agree, however, that because of the heat or cold or condition of the air on the other planets, there is little likelihood that any of them supports life.

For many years man has wondered about the possibility of space travel, and within your lifetime many great advances have been made. In fact, such rapid progress is being made in man's attempt to achieve space travel that we hear or read almost every day reports of new achievements in this field of study.

For a long time the scientists who are working toward future space travel have recognized two main obstacles — the reduction of the air content in the upper regions of the earth's atmosphere and the earth's tremendous gravitational force.



Study this diagram carefully. It tells us many things about the atmosphere around and above us. The atmosphere extends over 200 miles upward. One of the problems of future space travel will be to escape and return safely through the atmosphere. Why will it be necessary for space travellers to have pressurized suits and pressurized compartments? As man's exploration of the atmosphere and space beyond continues, the heights reached will change.

Our atmosphere

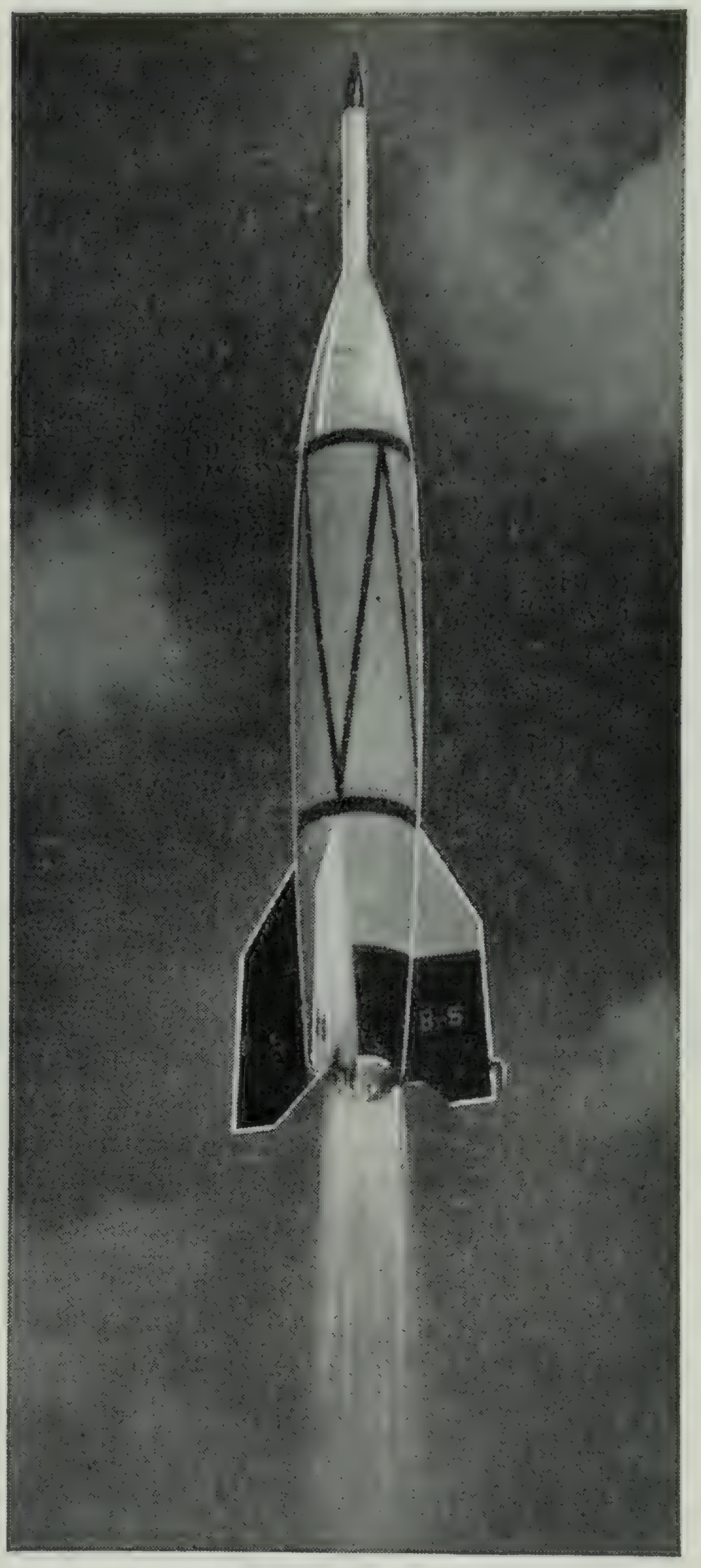
On the surface of the earth we live at the bottom of an ocean — an ocean of air, which we call the *atmosphere.* This layer of air around the earth is about 500 miles deep. This may seem like a very thick layer, but if you were to compare the earth to an orange, the atmosphere could be compared to the orange peel — not a very thick layer after all.

The air is most dense at the earth's surface, and higher up it becomes very thin. By studying the drawing on page 282 you can see how rapidly air pressure decreases. At 14 miles, for example, if you were not in a pressurized airplane or wearing a pressure suit, your blood would actually boil. Future space travellers will need special equipment containing air under pressure so that they can withstand the reduced pressure encountered high in the atmosphere and beyond.

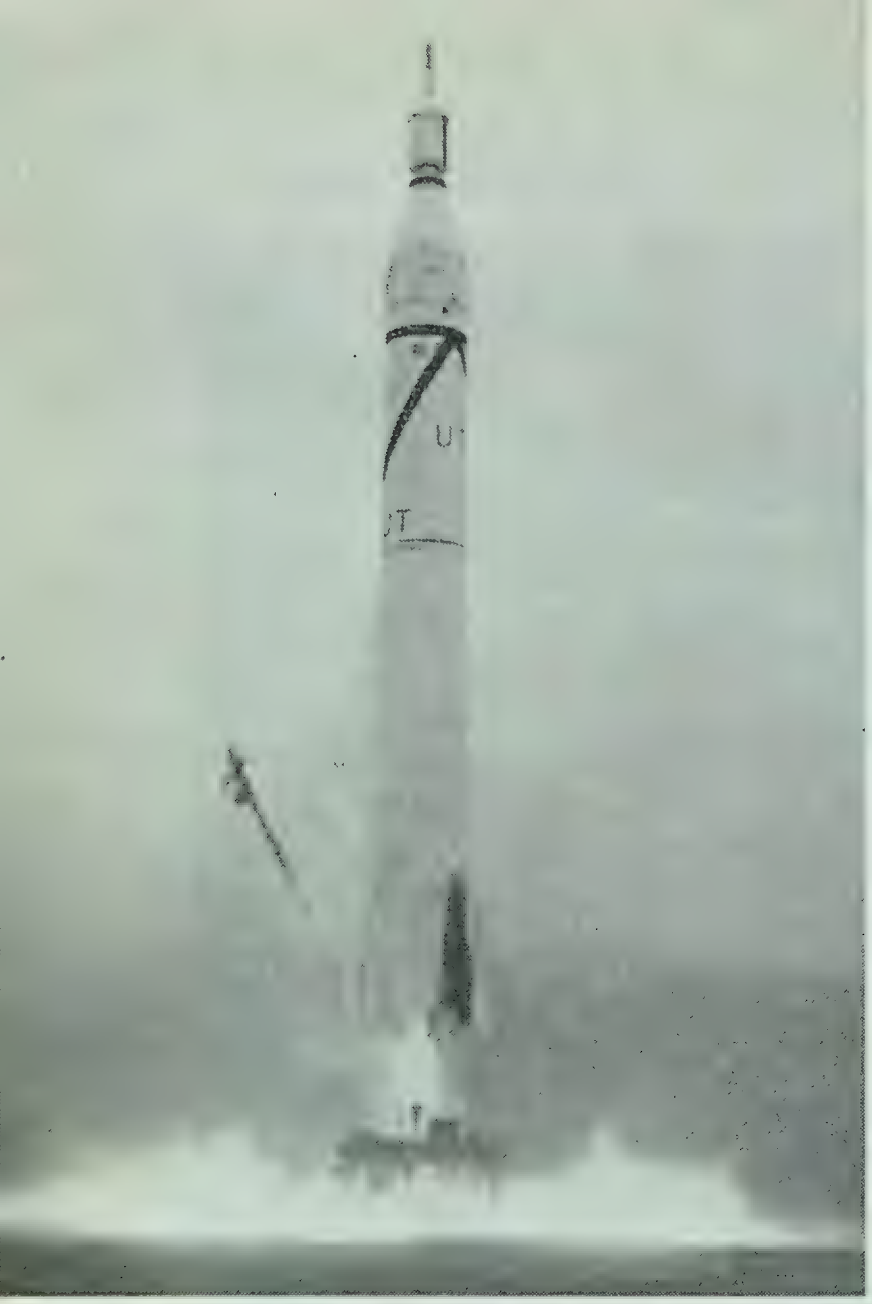
The reduced amount of air high above the earth will prevent airplanes from serving for space travel. Airplanes need air to operate their engines and to support their wings. For space travel, man will have to use another means of flight — the rocket.

Rockets to overcome gravity

You know that if you throw a ball into the air, the force of gravity will make it fall back to earth. Even a rifle bullet shot into the air falls back to earth. It does not travel fast enough to overcome the great force of gravity.



This two-phase rocket, known as WAC Corporal, in 1949 travelled 250 miles into space, a record altitude for any man-made device. The larger rocket climbed for 20 miles; then the two parts separated, and the smaller rocket shot upward. How was this experiment useful? Scientists think that a three-stage rocket will be necessary to make space travel possible. Watch newspapers, magazines, and television broadcasts for future developments in the use of rockets. (United States Army photo)



A huge three-phase rocket, carrying the earth satellite Explorer III in the tiny nose cone, as it leaves its launching pad early in 1958.

Scientists have found that the only way to attain enough speed to rise high into space is by means of rockets. In 1949, a two-phase rocket soared 250 miles above the earth. New fuels that could burn without air were discovered and improved. By 1957, three-phase rockets were developed capable of travelling over 18,000 miles an hour. In October of that year one of these rockets carried aloft for the first time a space satellite — a tiny man-made moon that attained enough speed and height to travel in its own orbit around the earth. The steady "beep" of its radio transmitter announced to the world one of the great modern achievements of science. Rushing along at a speed of over 18,000 miles an hour, the tiny satellite revolved around the earth every 90 minutes, and remained aloft for many days.

The three-phase, or three-stage, rockets used to launch this and other satellites are remarkable machines. Such a rocket is as tall as an 8-storey building. As its name suggests, it contains three parts (see the photograph on this page). The bottom part is mostly fuel which, when ignited, lifts the heavy rocket skyward. When this part has done its work, it falls off, and the next part or stage takes over, thrusting the rocket ahead with greater speed. Finally the second part falls off also, and the third part starts to burn, boosting into orbit the tiny satellite in its nose cone.

On the threshold of space

Soon after the launching of the first satellite in 1957, other scientists, who had also been preparing rockets and satellites, soon improved on the first one, and sent into orbit larger and more complicated satellites. Some of the satellites launched in 1958 reached orbits over 1000 miles above the earth, where they will continue to revolve for long periods of time. These satellites contain various instruments which for some time measured and reported the temperature, the amount of harmful rays encountered, the

amount of dust that strikes them, and other useful scientific information. The facts obtained will be useful in designing future rockets and clothing that may in time enable man himself to travel in space.

A book cannot keep up-to-date in reporting the latest achievements in the exploration of space. It will be necessary to read and listen for news reports about new developments. For example, you should watch for information on man's progress in his attempt to send rockets to the moon. Early in 1959, an attempt was made to launch a rocket to the moon. To escape the earth's gravitational pull it travelled over seven miles a second! This rocket missed the moon, but travelled beyond, to become a tiny "planet" revolving around the sun. This event suggests that in a few years we shall learn of many new advances in the exploration of the universe. It may truly be said that today we live on the threshold of space!

With the passing of every year, science has found the answers to more of the questions about outer space. Perhaps, in time, science will have solved the many problems that now make space travel impossible.

Meanwhile, we rush along our orbit around the sun, looking out from the "spaceship" earth at the timeless heavens, gazing at the beauty of the maze of stars, and wondering at their numbers and at the vastness of it all.

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. Tell how to use the sun by day and the North Star at night to tell directions.
2. What three units of time are based on the movements of parts of the solar system? To the astronomer, what does each unit measure?
3. How do many astronomers think the solar system began?
4. Briefly describe several of the kinds of stars that we can see. What do astronomers think is the probable life story of a star?
5. Do you think that space flight will ever be achieved? Why? What are some obstacles that must be overcome if space flight is to be possible?

SOMETHING TO DO

1. In your community there may be someone with a small telescope. Perhaps you can arrange to see the craters of the moon, Jupiter's four largest moons, and the wonderful rings around Saturn.

2. Because of the daily rotation of the earth, the Big Dipper seems to circle the North Star each night. Learn to use this "star clock" to tell time. Is the Big Dipper in the same position at the same time of night during each season? Why? In answering this question, remember

that, in addition to its daily rotation, the earth each year completes one revolution around the sun. Check for yourself the answer that you have given by observing and drawing the Big Dipper each month.

3. Have you a Science Club in your school? If so, making observations of stars is a good club activity. If your school has no science club, ask your teacher about the possibility of organizing one.

4. If you have a camera, try taking a picture of star trails. Point the camera toward a spot in the sky, secure it so that it does not move, and leave the shutter open for half an hour. In this way, it will be possible for you to obtain a record of the apparent movements of the stars.

5. Using *very small* circles of silver paper to represent stars, paste constellations on pieces of heavy paper. Space them as far apart as possible, to suggest the great distances between the stars. Draw your idea of the object whose name each constellation bears.

6. Watch newspapers and magazines for articles describing experiments dealing with space travel.

WHAT HAVE YOU LEARNED?

IMPORTANT SCIENCE IDEAS AND UNDERSTANDINGS

A

1. The sun provides us with heat and light, and enables plants to produce food.
2. The sun is a medium-sized star.
3. Day and night are caused by the daily rotation of the earth.
4. The earth revolves around the sun once every 365¼ days.
5. The tilt of the earth's axis brings about a variation in the length of daylight and in the sun's position in the sky, and causes our seasons to change.
6. The moon revolves from west to east around the earth, requiring about a month for each revolution.
7. During each revolution, the moon passes through four phases — new moon, first quarter, full moon, and last quarter.
8. The solar system includes the sun and nine planets.
9. The unit used in measuring distances to the stars is the light-year, which is the distance light travels in one year.
10. Units of time, such as the day, month, and year, are based on movements of the earth and moon.

(a) The foregoing sentences are all true statements of important science ideas and understandings. Read and discuss them carefully as a review of this chapter.

(b) The following sentences describe situations in which some of these ideas apply. To test your ability to apply ideas to actual situations, match the sentences in A with situations in B to which they apply.

B

1. On a February evening, Charles Parker had no difficulty locating Sirius, the brightest star of the winter sky, in the southeast. He was surprised to learn that the light he saw had left Sirius over eight years before.

2. One evening, Tony Romano watched the moon "rise" at seven o'clock. The next evening it did not appear until nearly eight o'clock.

3. Donna Kubo noticed that her shadow was longer at noon in winter than in summer.

4. Coal is often called "buried sunshine."

5. One night, Peter Stevens noticed that the crescent moon was on the right-hand side; two weeks later the crescent was on the left-hand side.

6. The astronomer helps to keep our time system exact by making observations and measurements of the movements of the bodies in the solar system.

IMPORTANT SCIENCE TERMS

A

rotation	galaxy	Venus
revolution	comet	Mars
axis	meteor	Jupiter
latitude	meteorite	Saturn
new moon	orbit	constellation
full moon	astronomer	light-year
eclipse	Mercury	Milky Way

To show that you understand and can use the science terms listed in A, match with the situations in B those terms which apply.

B

1. In the western sky during the evening in early winter, you can see four bright stars forming the Great Square of Pegasus, the flying horse.

2. Every year, the earth completes a nearly circular path around the sun.

3. One of the most beautiful sights to be seen through the telescope is the largest planet surrounded by several of its twelve moons.

4. Occasionally the moon passes directly between the earth and the sun.

5. One evening, Gary and Fred saw several streaks of light flash across the sky and disappear.

SCIENTIFIC METHOD AND ATTITUDE

1. When their class was learning why winter is cooler than summer, Mark Waltham and Walter Emery had a discussion about the statement that *the sun is closer to us in winter than in summer.* Mark refused to believe the statement. "It doesn't make sense," he said. "If the sun were closer in winter than in summer, winter would be hotter than summer." Walter decided to check the statement, and did so in two other science books and an encyclopaedia. He learned that the earth's orbit around the sun is not quite circular. The sun is 94,000,000 miles away in summer, and only 92,000,000 miles from us in winter.

(*a*) What attitude of a scientist did Mark lack when he refused to accept the statement or to consider it further?

(*b*) What two desirable attitudes did Walter show?

(*c*) Do you think we should accept at once every statement we read? Why?

2. Have you ever heard of "lucky stars"? Some people believe that the position of the stars and planets at the time we were born has a direct influence on the events of our lives. Although science has proved that there is no scientific basis for this belief, many people continue to try to predict the future from the stars.

(*a*) What scientific attitude is probably lacking in a person who thinks that events in our lives are affected by the positions of the stars?

(*b*) How could you, as a young scientist, check to find out if events foretold in predictions based on the positions of the stars usually do occur as predicted?

Trans-Canada Air Lines

I wield the flail of the lashing hail,
And whiten the green plains under;
And then again I dissolve in rain,
And laugh as I pass in thunder.

— Shelley

CHAPTER 7

CHAPTER 7

FORECASTING THE WEATHER

The weather and climate of the region in which you live greatly affect your activities. How do weather conditions influence transportation by land, sea, and air? What is meant by weather? What is the difference between weather and climate? Weather conditions are influenced by areas of high pressure and low pressure. How is air pressure measured? How do winds affect local weather conditions? How do movements of air masses influence weather? How is weather affected by the water vapor in the air? How do clouds help us to forecast the weather? By means of a school weather station, you can learn much about predicting the weather. In what ways does scientific weather forecasting aid us in our daily living?

HOW VERY IMPORTANT the weather is to all of us! Each day, it influences us in our choice of food, clothing, means of transportation, and recreation. One of the first things that we want to know each morning is what the weather is like. Is it likely to rain? What is the temperature? Is there a strong wind blowing? The answers to these and other questions are a guide to us in making necessary and important decisions.

The climatic conditions in various parts of Canada largely determine how people live. For example, the homes, food, clothing, and activities of the Eskimos are quite different from those of the people who live in the southern regions of Canada.

In recent years, scientists have made some progress in controlling weather conditions. For example, they have learned how to remove fog over air fields. They have had some success in producing rain by dropping pellets of dry ice or silver iodide into clouds. However, generally speaking, man has very little control over the

Study this illustration carefully to find out how these Eskimos have adapted themselves to the climatic conditions of the region of Canada in which they are living. (National Film Board photo)

weather; he therefore has to adapt himself to it. To do so, he builds homes that are well insulated and provided with good heating and ventilating equipment so that he can be comfortable indoors in winter as well as in summer. He provides himself with clothing of various materials that will meet his needs in all kinds of weather. He builds sturdy ships that can navigate safely through heavy storms at sea. He makes railroad trains and automobiles more comfortable by air conditioning. These are but a few of the ways in which man has adapted his manner of living to meet varying weather conditions.

Weather provides us with many of the pleasures that we enjoy from day to day — beautiful sunny days and clear moonlit nights, colorful sunsets, awe-inspiring electrical displays accompanying thunderstorms, interesting cloud formations, delicate patterns in snowflakes, rippling waves on calm lakes, roaring breakers off-shore, the patter of rain on a roof, the lashing of wind-driven rain against a window pane. These are experiences that many of us have learned to appreciate. The study of this chapter should help you to understand the causes of these weather conditions and other wonders of the weather.

WEATHER AND CLIMATE

Although man has very little control over the weather, he has found out many things about it by scientific research and is therefore able, to a considerable extent, to forecast weather changes and to regulate his activities accordingly.

What is the difference between weather and climate?

When we speak of *weather*, we mean the conditions of the atmosphere from day to day with regard to such factors as temperature, humidity, clearness or cloudiness of the sky,

direction and velocity of the wind, and moisture in the form of rain or snow.

The term *climate* has a more general meaning. It refers to the general average weather conditions prevailing over a period of years, without regard to temporary weather changes. Hence the climate of a given part of the world is a more or less permanent condition, while weather is subject to frequent change. For example, on a day when it is raining in an area such as south-eastern Alberta, where it is usually dry, we would say that the weather is wet. However, the climate of this same area is described as dry because the amount of rain and snow from year to year is light.

SOMETHING TO DO

1. Listen to a weather-forecast report on your radio or television. Make a list of the different weather factors mentioned, such as temperature, wind direction and velocity (speed), etc.

The following day, compare the actual weather conditions with those that were forecast. Was the "weather man" right?

Repeat this exercise each day for a month.

2. Briefly describe the summer climate and winter climate in the part of Canada in which you live.

How does climate affect our way of living?

In regions lying far from the equator, where the sun's rays are always slanting at a low angle, the climate is extremely cold, and living conditions are unfavorable. Homes are very crude. Eskimo igloos, for example, are constructed of blocks of ice. Clothing is made of the skins of animals, and food consists chiefly of raw meat obtained with great labor and danger. In these areas, the struggle for existence has been so difficult and natural resources have been so scarce, that the races of people who live there have remained quite primitive. Look for evidence of this in the illustration on page 291.

In regions lying near the equator, the life of the native is equally primitive. There, clothing is scanty and of light material; homes are simple and poorly constructed. (Study the illustration on page 293.) Living is easy because of the abundance of food that can be secured with little effort. The hot climate makes work and mental activity difficult.

It is in the temperate zones of the world that the inhabitants have had most interest in mechanical, scientific, and cultural developments. In these regions, though living demands real effort, conditions are such that man has some energy left for trying out different ways of doing things and making changes in his way of living.

SOMETHING TO DO

1. Examine maps, and list by name some of the countries lying in the temperate zones. Compare the accomplishments of the people of these countries with those of the regions of extreme temperatures. How does climate affect the manner of living? The initiative of people?

A home in a country where the weather is always warm. Compare the construction of this dwelling with that shown on page 291. Why are the natives dressed so differently in the two cases? (Ewing Galloway photo)

2. "The kinds and character of the plants and animals found in your environment are determined by climate." Give examples in support of this statement.

How are man's activities limited by weather conditions and climate?

Agriculture.—Agriculture depends upon the weather. Each spring, the farmer and the gardener depend upon warmth and moisture to germinate the seeds that they have sown and to speed their development. June rains are very welcome. If weather conditions remain favorable throughout the growing season, a good harvest is realized. A few days of hot, dry winds in early July, however, will tip the heads of grain with white, and a prolonged drought will literally burn up the crop which once looked so promising. An intensely hot day or two may bring in its wake a devastating hailstorm, which in a few minutes may damage the farmers' crops beyond recovery. Early frosts, too, sometimes take their toll of fruit, wheat, and other crops.

When rainfall is abundant, and the weather hot and humid, the conditions are favorable for the spreading of the fungus that causes wheat rust. The estimated damage caused by rust to the wheat crop of Canada in a single year has amounted to as much as $100,000,000.00. Grasshoppers, cutworms, and other destructive insects thrive during warm, dry weather, while cold, wet weather helps to keep them under control.

High winds and lack of rainfall are factors that contribute to soil-drifting, which in some years has caused great damage to the fertile plains of the Canadian prairies.

Climate has an important bearing on the kind and quality of plants that can be grown successfully in any area. The excellence of Western Canadian wheat for bread-making purposes, the striking color of the Red Delicious apples of the Okanagan Valley, and the exceptional flavor and keeping

The winds have piled up large drifts of soil against this farmer's barn. In dry areas, wind, by causing extensive soil drifting, often destroys the soil's ability to grow crops. (J. I. Case Company photo)

Deep-sea fishing schooners formerly fought their way through rough Atlantic seas off the coast of Nova Scotia. High gales often bring great peril and disaster to fishermen. (Nova Scotia Film Bureau photo)

quality of the Northern Spy apples grown in Eastern Canada, are largely due to the distinctive climates of these regions. Such crops as cotton and sugar-cane, and such fruits as bananas and oranges, are not suited to Canadian climatic conditions and therefore cannot be successfully grown in this country.

OTHER INDUSTRIES. — *Lumbering, fishing, trapping, building,* and *road construction* are other industries that are very dependent on the weather. Mention at least one way in which each of these industries is affected by the weather.

TRANSPORTATION. — The ease and speed with which we can get from one place to another depends to a large extent upon the weather. If the streets are icy, riding a bicycle on them is dangerous, and even walking is hazardous. Our speed, comfort, and safety in automobile travel are greatly influenced by the iciness of the highway, and by rain, sleet, snow,

Workmen "dig out" a train that was stalled in a snowbank for three weeks. The photograph illustrates how weather affects important activities, such as transportation. (Larry Shaw photo)

Weather conditions that lead to flooding can cause great damage and suffering. (United States Weather Bureau photo)

A sleet storm often disrupts communication by breaking down telephone or telegraph lines. (United States Weather Bureau photo)

fog, and other weather conditions. Air travel is dependent to an even greater degree on the weather. If visibility is very poor, the airplane will not be allowed to take off, and the flight will be cancelled, causing considerable delay and inconvenience. High winds, sleet, snow, and thunderstorms affect the speed and safety of air travel. Travel by sea is also greatly affected by weather conditions. In winter, heavy snowfalls often disrupt railroad, highway, and street traffic (see illustration on page 294). In spring, snowslides and flooding rivers can wash out bridges and make highways and railroads impassable.

Communication.—When telegraph and telephone wires are weighed down with sleet or blown down by gales, long distance and local communication is disrupted (see illustration on this page). Electrical storms and displays of "northern lights" interfere with radio broadcasting.

Recreation. — Picnicking, hiking, camping, golfing, tennis, baseball, rugby, skiing, swimming, and fishing are some of the activities that are

Some winter sports are dependent on cold weather and snow. What form of recreation are these men enjoying? What other sports require favorable weather conditions? (United States Forest Service photo)

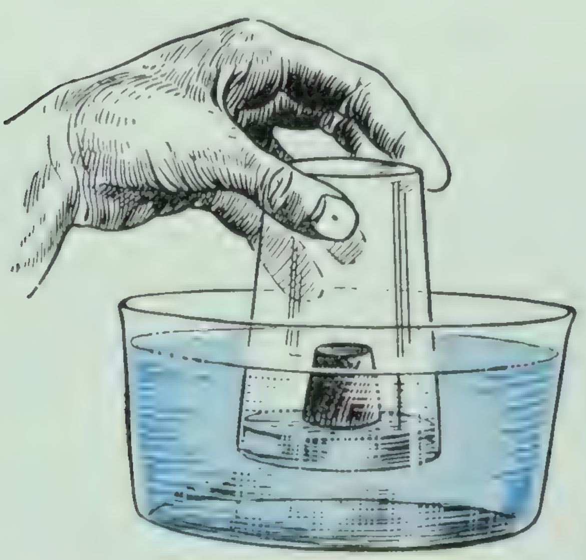
dependent upon the weather. There is not much fun in camping when it is raining heavily or in fishing when the wind is blowing strong and cold. When planning an outing, it is wise to check the weather forecasts, for the success of such an activity largely depends on favorable weather.

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. Clearly explain the difference between weather and climate.
2. In what zones of the earth have the most progressive races of people been developed? Explain.
3. How do weather conditions affect agriculture?
4. Make a list of the ways in which the weather affects such industries as fishing, transportation, and merchandising.
5. How does climate determine the products of the different sections of North America? In your answer, discuss such products as cereals, fruits, livestock, and fish, with reference to both kind and quality.

AIR PRESSURE INFLUENCES THE WEATHER

You have learned that weather is the condition of the atmosphere, or layer of air above the earth's surface. Have you ever wondered whether air takes up space? Here is an experiment that you should do to find out.



What prevents the water from rising farther into the tumbler?

SOMETHING TO DO

Problem. — Does air occupy space?

Apparatus and Material. — A glass tumbler; a large dish or pan filled with water; a cork.

Method. — (1) Float a small cork in the dish of water. (2) Place a glass tumbler, mouth down, over the cork, and push the tumbler into the water. (3) Watch the cork to see if the water rises in the tumbler.

Observations. — Has the water risen to fill or nearly fill the tumbler?

Conclusion. — If the water did not rise to fill the tumbler, why didn't it? What do you think occupies the space inside the tumbler, thereby keeping the water out?

Now answer the question asked in the problem that is stated above, at the beginning of the experiment: Does air occupy space?

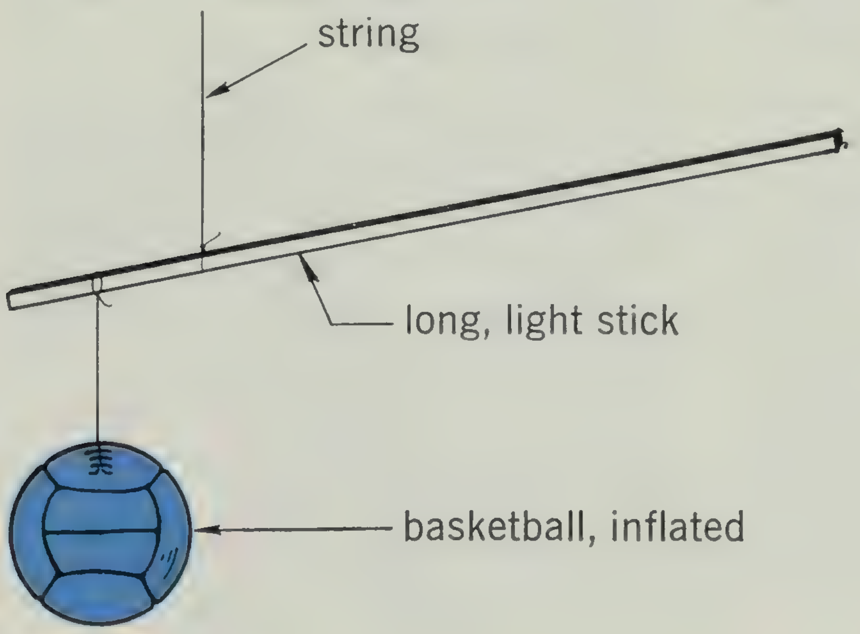
These three boys are using the experimental method to find out for themselves facts about air pressure. What step of the scientific method does this illustrate?

Other substances, such as iron, coal, wood, and water, which occupy space, also have weight; does air also have weight? If you will do the following experiment carefully, you will be able to answer this question.

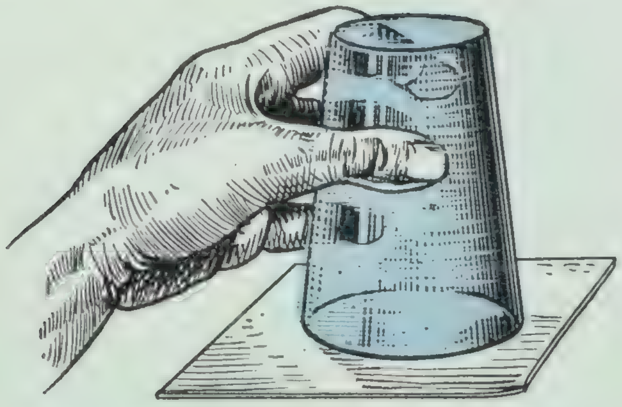
SOMETHING TO DO

Attach an empty football or basketball to one end of a long, light stick. Suspend the stick as illustrated below, placing the string so that the ball and stick are balanced. Using a bicycle pump, pump air into the ball until it is hard. What happens? What do you conclude? You should repeat this experiment several times.

A cubic foot of air, under normal conditions at sea level, weighs 1¼ ounces. Do you think that you could lift the air in an ordinary room (15′ × 15′ × 8′)? Find out how much this volume of air weighs.



An experiment to find out if air has weight. This is a delicate experiment, and great care must be taken in setting it up. Repeat it several times to check your results.



What prevents the water and the card from falling from the tumbler?

Does air exert pressure?

As you know, the layer of air (atmosphere) around the earth extends upward for several hundred miles. You also know that air has weight. Is there a great weight of air above and around us, exerting pressure on us? Here are several experiments to find out whether air exerts pressure.

SOMETHING TO DO

1. Fill a tumbler to the brim with water. Holding your hand tightly over the mouth of the tumbler, turn the tumbler mouth down, and lower it into a basin of water until the mouth of the tumbler is just below the surface of the water. Slip your hand out. What happens? Why does the water not run out of the tumbler?

2. Fill a tumbler to the brim with water. Place a piece of thin cardboard (about an inch larger all around than the mouth of the tumbler) over the mouth. Holding the cardboard firmly in place, turn the tumbler upside down. Remove your hand from under the cardboard. What happens? What must be pressing against the cardboard to hold it in place?

3. Insert the tube of a medicine dropper into a glass of water. Squeeze the bulb. What happens? Release the bulb. What happens? What causes the water to rise into the medicine dropper?

4. It is easy to suck water through a glass tube. Insert a glass tube through the hole in a rubber stopper and fit the stopper snugly into the mouth of a suitable flask filled with water. Try to suck water up into the tube from the flask. Why is it easy to suck water into the tube from an open dish or flask, but impossible to do it from the closed flask?

5. Close the mouth of a paper bag around your finger, then remove your finger. Blow into the bag. What happens? Why? Suck air out of the bag. What happens? Why?

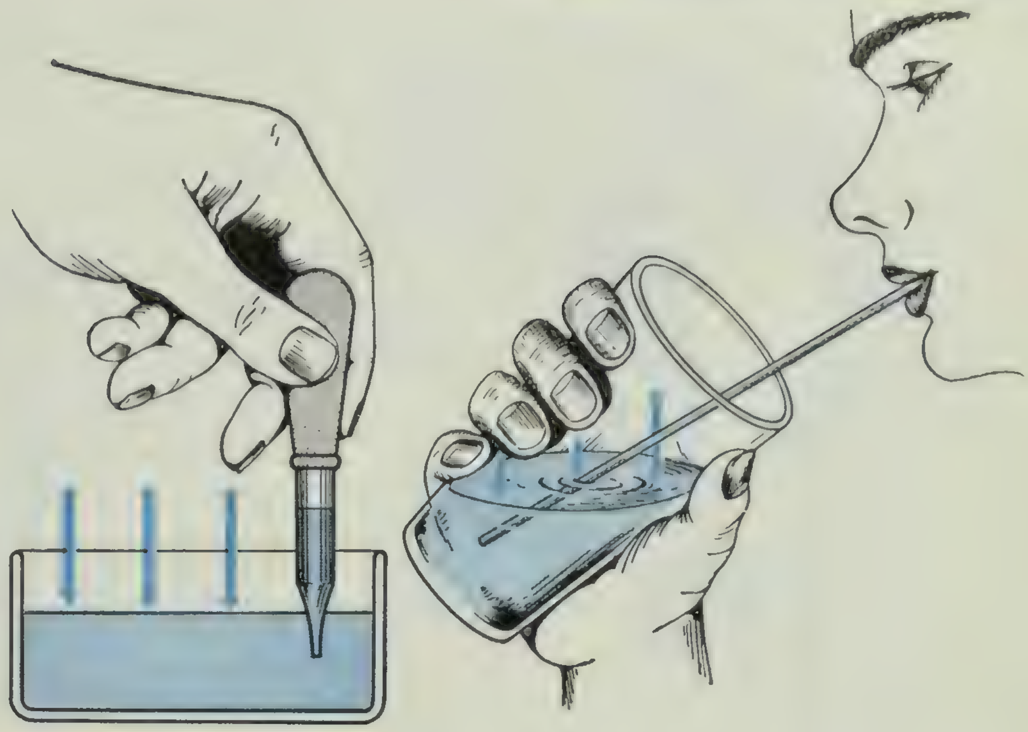
6. Boil an egg for about ten minutes, cool it in water, and carefully remove the shell. Using a *dry* milk bottle, twist a 4-inch square of paper, set fire to it, drop it into the bottle, and quickly place the egg in the mouth of the bottle. What happens? Why?

NOTE. — Plan a way to force the egg out of the bottle. When you blow into a balloon, the air pressure inside the balloon is increased. How could the air pressure in the bottle be increased and used to force the egg out?

Could you tell what was happening in each experiment? What part did air pressure play in each one?

In the first experiment, where was the air pressure exerted, that it was able to hold the water up?

Were you surprised at what happened in the second experiment? In what direction was the air pressure exerted that held the card in place under the tumbler of water?



How does air pressure raise the liquid in the medicine dropper and in the straw?

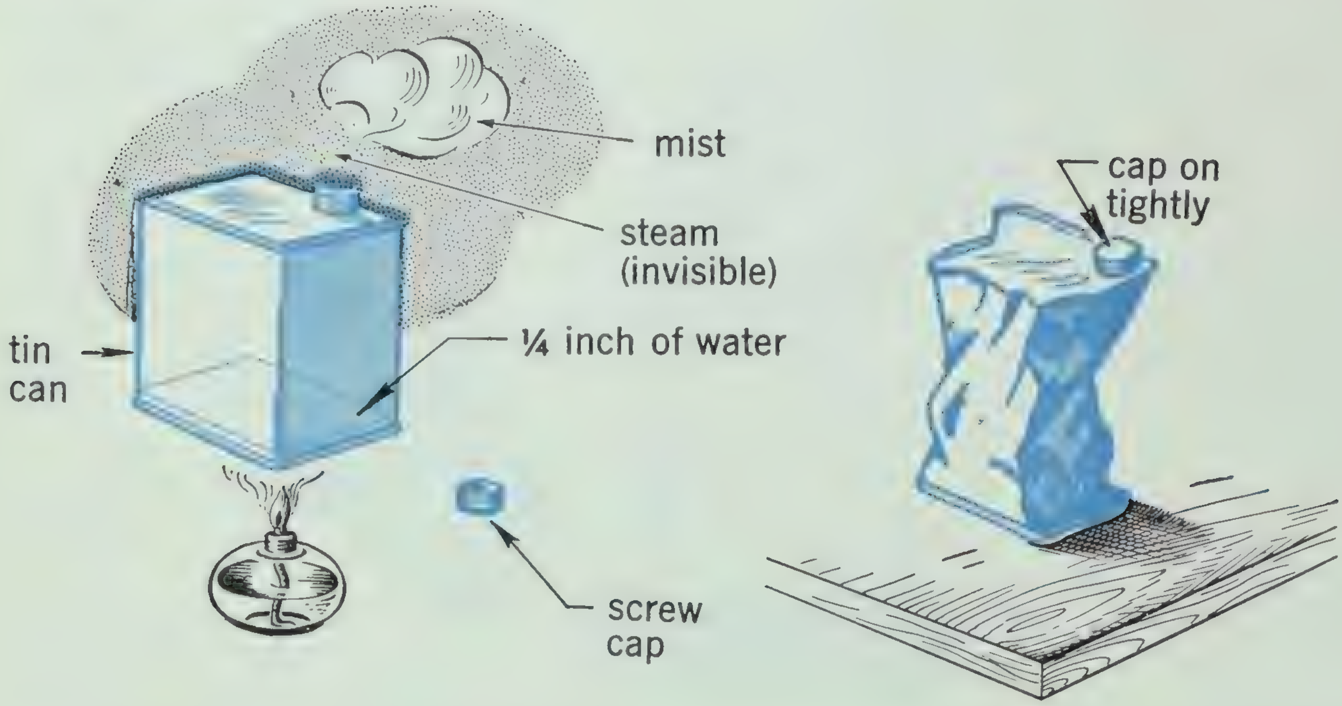
In the third experiment, did you conclude that air pressing on the surface of the water forced some of the water up into the empty bulb of the medicine dropper?

When you suck water up through a tube, as in the fourth experiment, air pressure on the surface of the water forces the water up the tube. This is how it works. First, by changing the size of the space inside your mouth, without letting any more air in, you reduce the air pressure in your mouth. Then air pressure on the surface of the water in the glass pushes some of the water up the tube. But when you close the flask in the second part of the experiment, you keep the air outside from getting in, and when you try to suck water through the tube, the air pressure in the flask is not great enough to force the water up the tube.

In the experiment with the paper bag, did you conclude that the bag swelled out because you increased the air pressure inside it, and collapsed because the pressure of the air on the outside was pushing on it?

Are you able to explain why the egg was forced into the bottle in the last experiment? Air expands, or becomes larger, when it is heated. When you dropped the burning paper into the bottle, it heated the air and some of it escaped. Then, as the air in the bottle cooled, it contracted, or became smaller. Thus there was less air pressure in the bottle than outside, and the greater air pressure outside pushed the egg into the bottle.

Were you able to use air pressure to get the egg out of the bottle? Here is one way that you might try to get it out. Rinse the ashes from the burning paper out of the bottle. Then turn the bottle upside down so that the smaller end of the egg is in the neck of the bottle. Then press the mouth of the bottle firmly against your lips,



An experiment to demonstrate the great force of air pressure. Be sure to remove the can from the heat before you put the cap on. Then let it cool off. Why does it collapse?

and blow as hard as you can into the bottle, just as if you were inflating a balloon. Then quickly take the bottle away from your mouth. If necessary, repeat several times.

From these experiments you have learned that air exerts pressure. Air presses down on the surface of the earth with a force of about fifteen pounds per square inch. The pressure of the air varies somewhat from day to day and from one region to another. Some areas have low and others high atmospheric pressure. Air tends to move in great circular movements from high pressure areas to low pressure areas. The movements of air or winds have an important influence on our weather.

How is air pressure measured?

Air pressure is measured by instruments called *barometers*. There are two types of barometers, namely, *mercury barometers* and *aneroid barometers*.

The *mercury barometer* was invented by Torricelli, who was a pupil of Galileo, a famous scientist of the seventeenth century. Torricelli's discovery furnished the first conclusive proof that air exerts pressure, and was the forerunner of the science of weather forecasting. It would not be difficult for you to construct a mercury barometer. Directions for constructing and using such an instrument are given in the experiment that follows.

SOMETHING TO DO

Make a simple barometer and use it in measuring the pressure of the air.

You will need a glass tube a little more than 30 inches in length, closed at one end and open at the other; a dish,

tumbler, or beaker; a pound of mercury; a piece of rubber tubing 6 inches in length; a glass funnel.

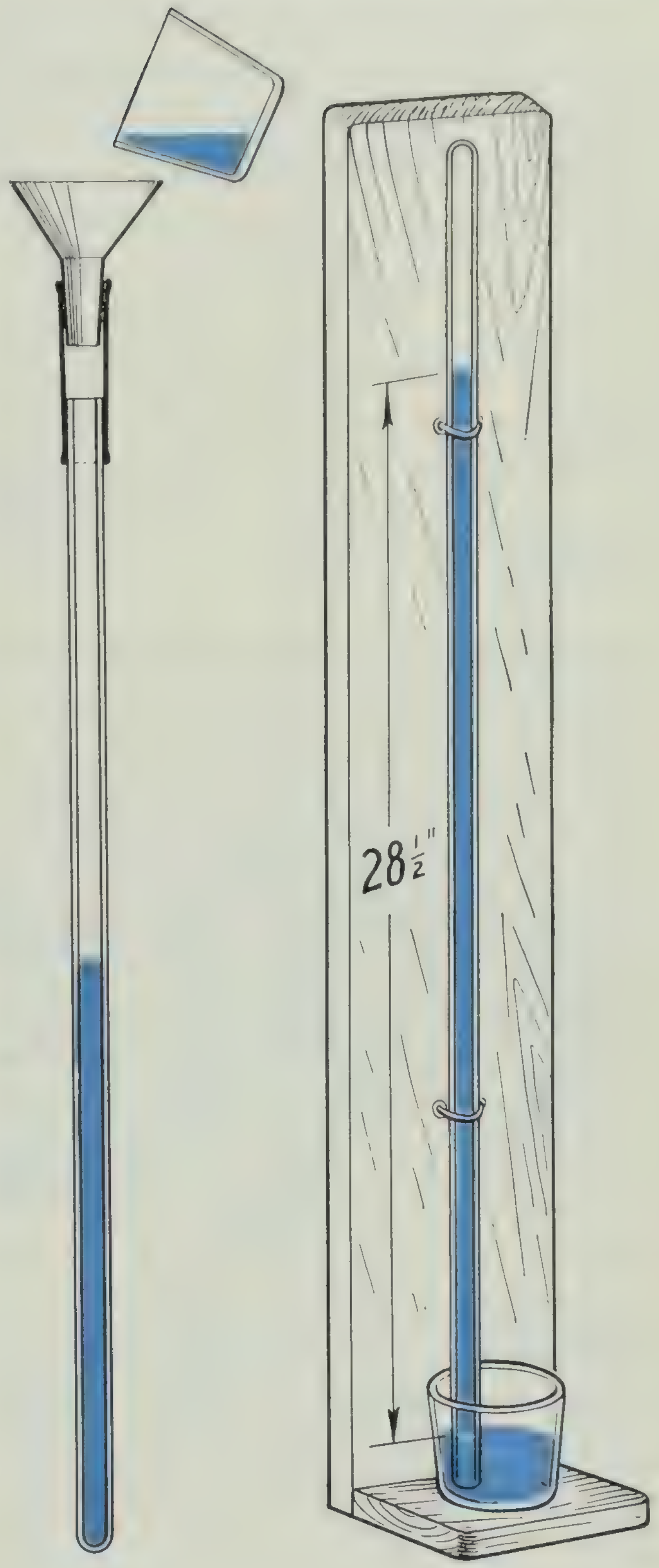
Connect the funnel to the glass tube by means of the rubber tubing (see diagram on this page). *Slowly* pour the mercury into the funnel, a little at a time. To remove all the air bubbles that have been trapped in the mercury, *tap the tube gently with your finger as the tube is being filled.* It is important to do this, as a barometer will not register air pressure correctly if there is any air trapped in the tube. Continue slowly adding mercury a little at a time and tapping out the air bubbles with your finger until the tube has been filled.

Pour the remaining mercury into the dish. Remove the rubber tubing and funnel. Close the end of the tube by holding the end of a finger over it. Turn the tube upside down and lower it beneath the surface of the mercury in the dish. Then remove your finger from the mouth of the tube.

What do you observe? Bearing in mind that no air has been allowed into the barometer tube, how do you account for the empty space at the top of the tube? Why does all the mercury not run out of the barometer tube? What does the height of the mercury in the tube tell us about the air pressure at present?

You now have a simple mercury barometer. Using a yardstick, carefully measure the distance in inches from the *surface of the mercury in the dish* to the *top of the mercury in the tube.* You thus obtain a measurement of the air pressure in inches of mercury. What do you find it to be?

Mount your barometer as suggested in the drawing on this page. Continue to make observations and record the air pressure for a week or more.



How to make a mercury barometer for your weather station. The barometer measures air pressure. Why is such an instrument useful in weather forcasting?

From your experiment, you have learned that the air pressure holds up the column of mercury in the tube of the barometer. Air pressure varies

somewhat from day to day and from locality to locality. If the air pressure increases, the mercury is pushed higher up in the tube. On the other hand, if the air pressure becomes less, it cannot support as high a column of mercury, and some mercury will run out of the tube into the dish. Therefore, by measuring the height of the mercury in the barometer, we can obtain a measurement of the air pressure.

Low pressure and high pressure areas

When the air pressure is low in your locality, you are in an area of low pressure, roughly circular, which may be several hundred miles in diameter. Likewise, when the air pressure is high, you are in an area of high pressure. Low pressure areas and high pressure areas, in general, move across Canada from west to east. Usually, a low pressure area is followed by a high pressure area which in turn is followed by a low pressure area (see page 303).

There is a definite relationship between the barometer reading and the weather. A sudden drop in the barometer indicates the approach of a low pressure area, which is often accompanied by stormy weather. In a high pressure area, the weather is usually fair and clear. When the barometer shows that the air pressure is rising, it means that a high pressure area is approaching, bringing with it fine weather. The barometer, therefore, is a very useful instrument in predicting the weather.

Winds blow from high pressure areas to low pressure areas. The positions of these areas, therefore, determine the wind direction.

At sea level, normal atmospheric pressure is equal to 30 inches of mercury. As one goes from sea level to a higher altitude, the mercury in the barometer falls, thus indicating lower air pressure. Why is the air pressure on a mountain less than the air pressure at sea level?

Aneroid barometers, since they contain no liquid, are adapted for a variety of uses. They are handier than mercury barometers, but are not as accurate (see illustration on page 333). One widely used instrument of this type is the *altimeter*, an instrument used in airplanes to register altitude. By measuring changes in air pressure as an airplane rises, an altimeter shows the height of the airplane above the ground.

If possible, you should examine a barometer of the aneroid type to learn how it operates. Many homes and schools have various forms of aneroid barometers.

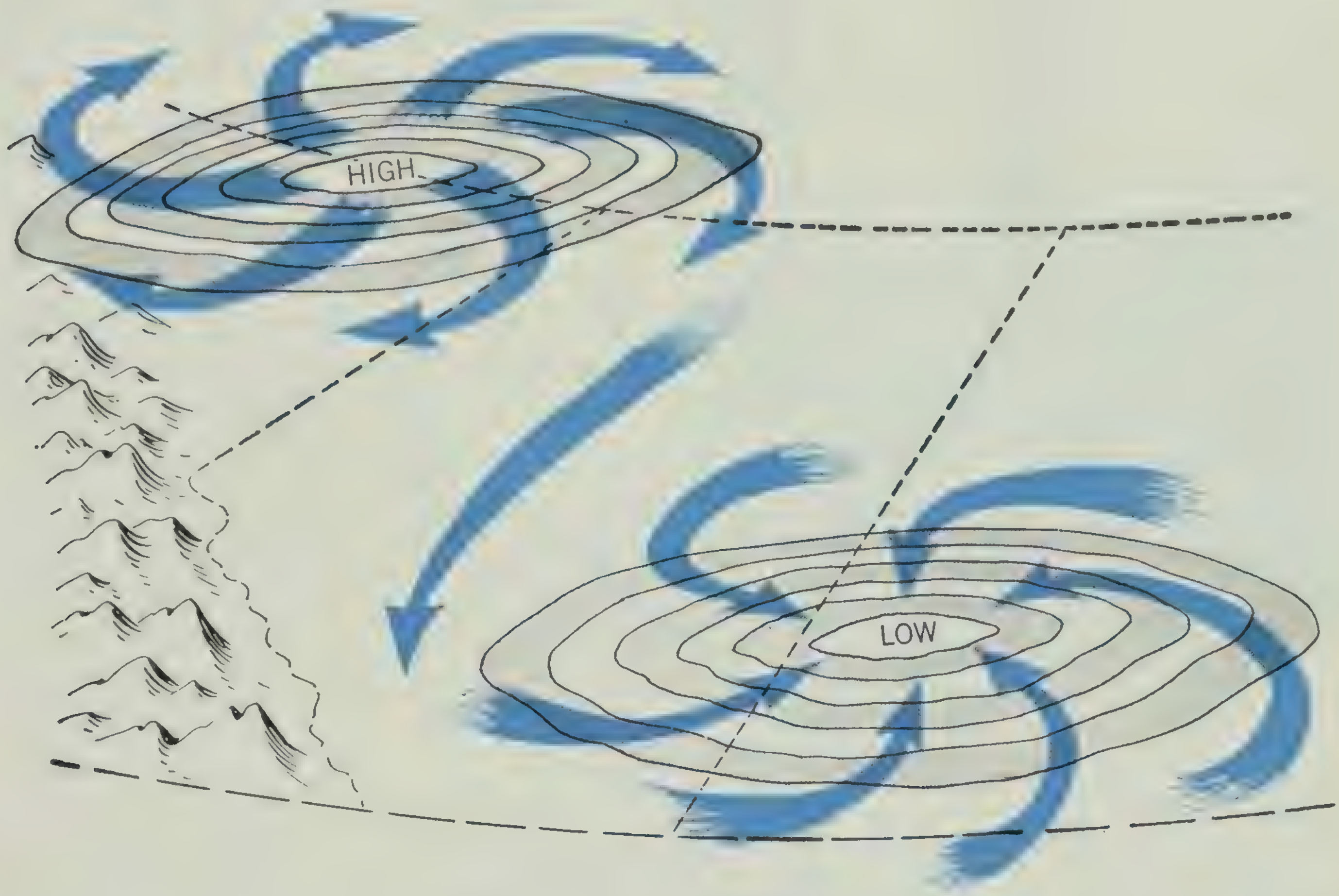
TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. Does air exert pressure? How do you know?
2. What instruments are used to measure air pressure?
3. Why is the air pressure at sea level greater than at 2000 feet above sea level?

4. What relationship exists between the barometer reading and the weather?

5. Tell how to make a simple mercury barometer.

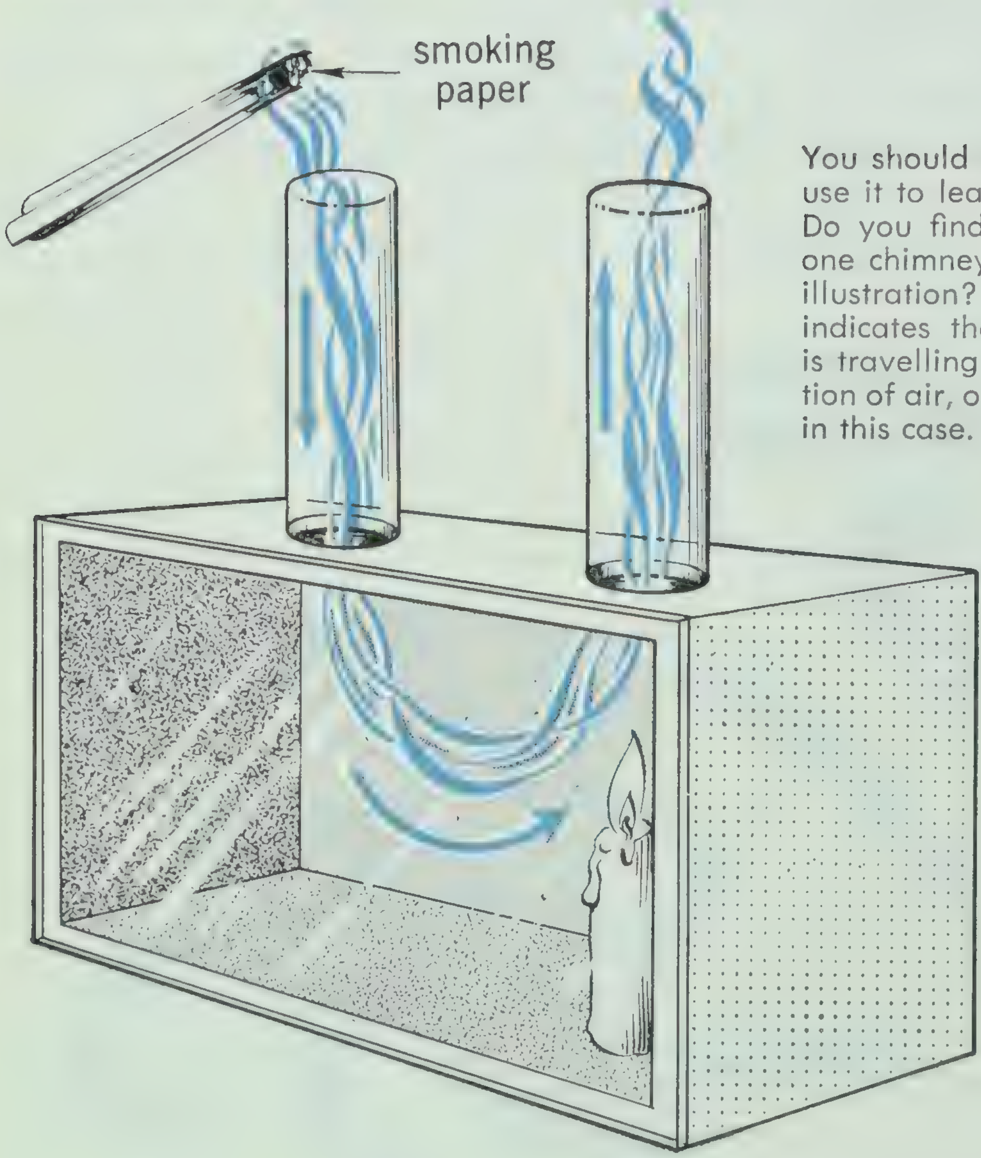
6. Why are aneroid barometers often used instead of mercury barometers?



A high pressure area and a low pressure area moving across the Prairie Provinces. Notice that air flows from the "high" to the "low." Winds move *out* from the "high" in a *clockwise* direction. Winds blow *into* the "low" in a *counterclockwise* direction. What kinds of weather usually accompany "lows" and "highs"? High pressure areas are often called anticyclones; lows are called cyclones. The word *cyclone* does not mean a violent storm, a sense in which it is often used incorrectly.

HOW WINDS AFFECT THE WEATHER

Have you ever experienced a day in winter when the temperature was zero and a 30-mile-an-hour wind was blowing? Such days are bitterly cold. On other days when the temperature is the same and there is little or no wind, the weather does not seem so cold. Wind affects local weather conditions in a number of ways. One very important way is that it may



You should assemble this apparatus and use it to learn about convection currents. Do you find that the smoke goes down one chimney and up the other, as in the illustration? The movement of the smoke indicates the direction in which the air is travelling. Explain fully how a circulation of air, or convection current, is caused in this case.

cause air to move up a slope, and, as a result, clouds with rain or snow may follow. This often happens in mountainous areas, as when westerly winds blowing from the Pacific are forced up the western Rocky Mountain slopes.

What makes the wind blow?

Winds are large air currents. What starts the air flowing? What determines the direction of the flow?

SOMETHING TO DO

Problem. – What is one cause of wind?

Apparatus and Material. – A wooden chalk box, a piece of glass the same size as the top of the box, a short candle, two lamp chimneys or glass cylinders, a slightly damp paper towel.

Method. – On one side of the box and close to each end, cut a round hole about one inch in diameter. Set up the apparatus as shown in the illustration on this page. Light the candle and set it directly below one of the chimneys. Close the front of the box by sliding the glass window into position. Light the paper towel and hold it over the second chimney.

Observation. – What path is followed by the smoke?

Conclusion. — Why does the smoke move down through the one chimney and up through the other? What does this tell you about the cause of wind?

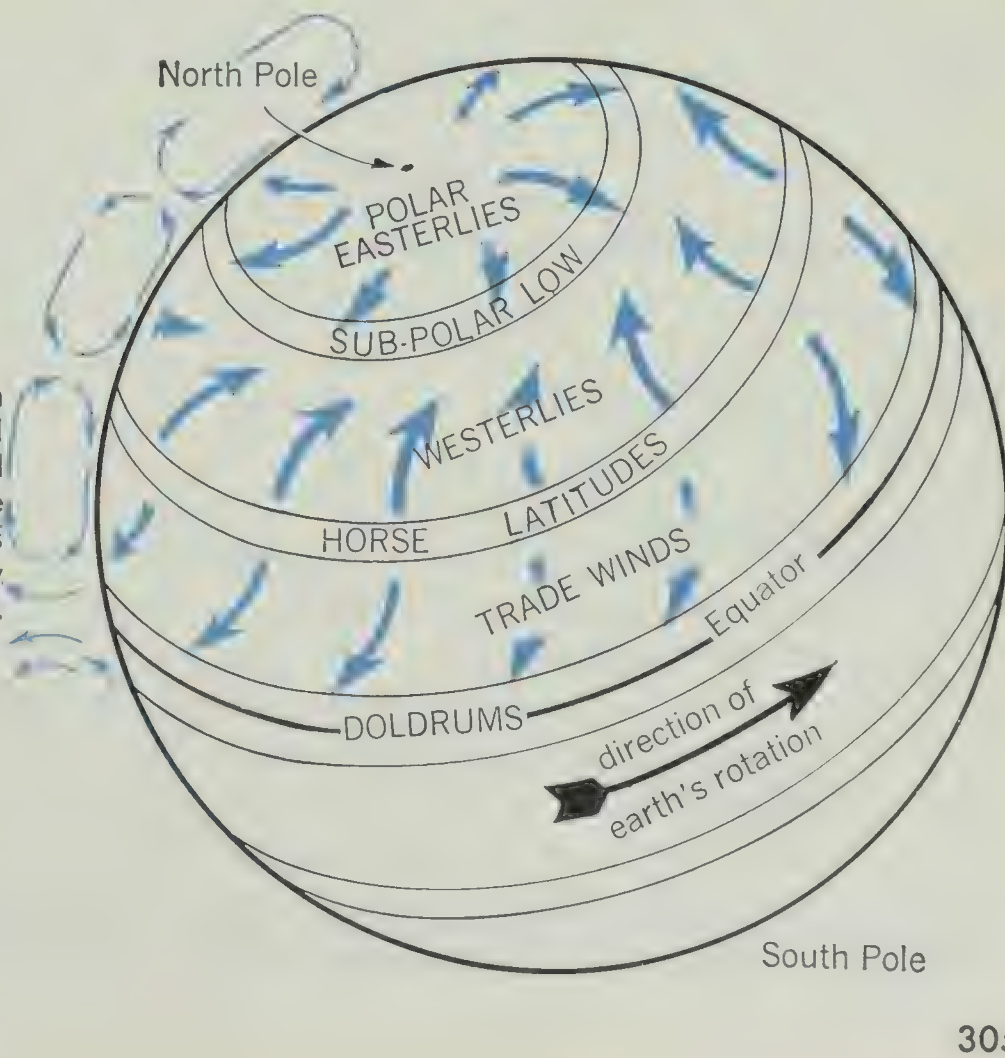
In your experiment, you observed that the smoke from the burning paper moved down through the chimney over which the paper was held, and came out the other chimney. It was carried in this path by a moving current of air called a *convection current*. What caused this current?

Perhaps you already know that when gases are heated they expand. Air is a mixture of gases. In your experiment, the heat of the candle caused the air over it to expand, and so to become lighter. The surrounding colder, heavier air then settled down and forced the warmer, lighter air up through the chimney above the candle. An air current was thus set up, the path of which was traced in your experiment.

Some winds of the earth are caused in the same way. Masses of air over warm areas are heated. As a result, they expand and become lighter. Colder, heavier air flows in and replaces the lighter air. The movement of air sets up air currents or winds.

Wind belts of the earth

If you will notice the direction of the wind each day for several weeks, you will probably observe that west winds occur more frequently than winds from any other direction. As you know, areas of high pressure



Wind belts of the northern hemisphere. Notice that all arrows, showing wind direction, curve to the right. The smaller arrows at the left show the flow of air in each wind belt.

and low pressure usually move across Canada from west to east. We say that our *prevailing winds* are west winds.

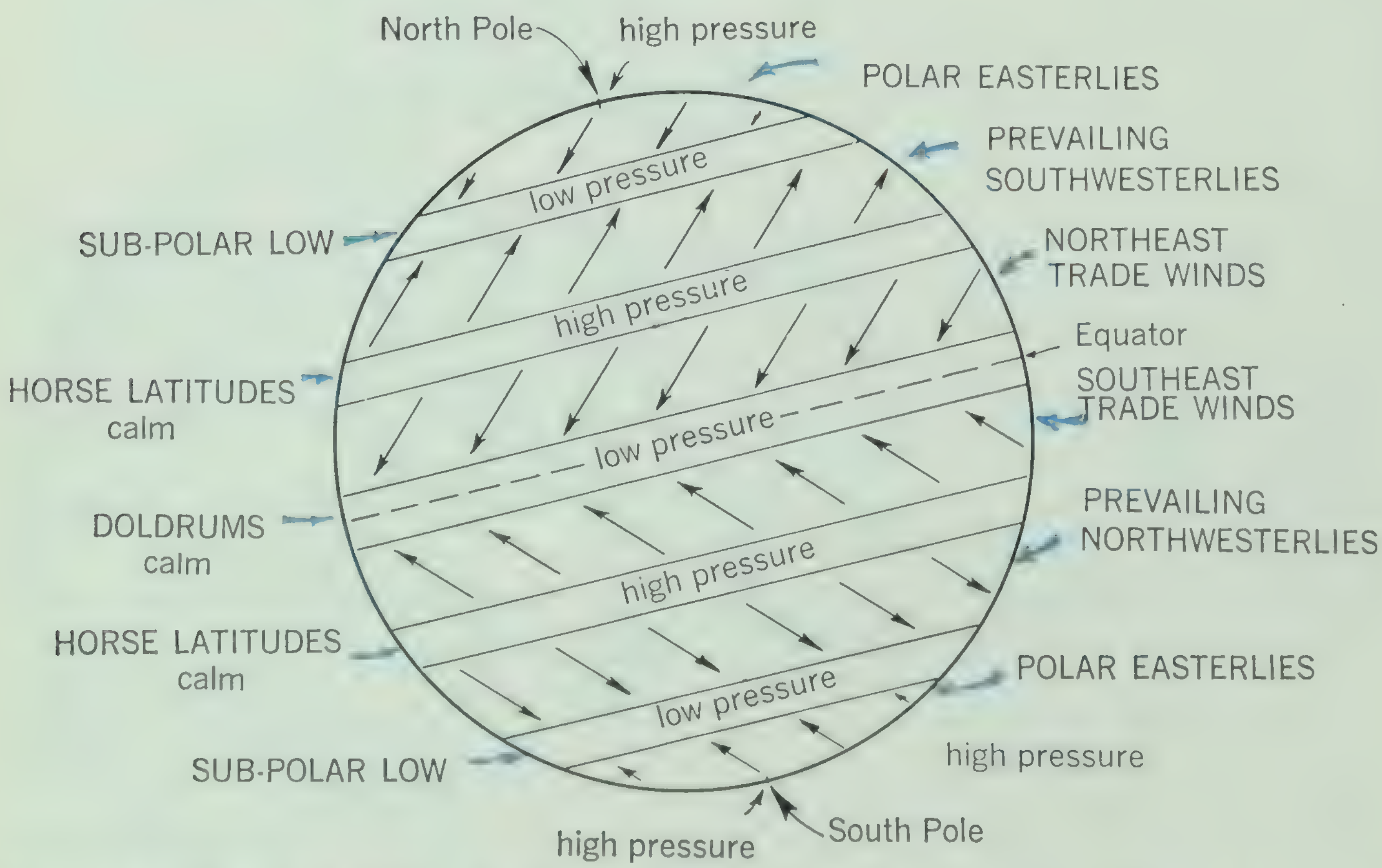
The surface of the earth is divided into a number of large wind belts. Most of Canada is in the *westerlies*, or the belt where the prevailing winds are from the west.

The drawing on page 305 and on this page will help you to locate the earth's wind belts on the globe and to understand how they are caused.

The main cause for the different wind belts is the fact that areas near the equator receive more heat from the sun than areas nearer the poles. As you have learned from the experiment on page 304, uneven heating of air is one cause of winds.

Near the equator, where the sun shines directly down on the earth, the air is heated more than at any other place on the earth. Because air expands when it is heated, this belt of air, known as the *doldrums*, is made up of light air. Cooler, heavier air on each side of the doldrums flows toward the doldrums, forcing the lighter air upward. Thus the doldrums form a calm area of low air pressure.

The next wind belts, one in each hemisphere, are made up of the winds blowing toward the doldrums. If the earth remained still, these winds, known as *trade winds*, would blow directly from the north in the northern hemisphere, and directly from the south in the southern hemisphere.



The wind belts of the earth. Account for the direction of the winds in each belt. Compare this map with a globe, and locate on the globe the area of each wind belt.

However, the eastward rotation of the earth has an important effect on the direction of these and other winds. In the northern hemisphere, all winds are turned toward the right, and in the southern hemisphere winds are turned toward the left.

Look at the trade winds north of the doldrums in the drawing on page 306. As they move toward the south they are turned toward the right. From what direction are they blowing? Because these trade winds blow from the northeast, they are called northeast trade winds. The winds blowing toward the doldrums from the south are called southeast trade winds.

Because the sun's direct rays fall south of the equator from September 21 until March 21, and north of the equator from March 21 until September 21, the doldrums and trade winds shift farther to the south during our fall and winter, and farther to the north during our spring and summer.

The air that is constantly pushed upward from the doldrums flows toward the poles. At the *horse latitudes* it settles back toward the earth's surface. This downward flow of air causes a high pressure area at the horse latitudes. Some of the descending air pours out toward the doldrums, and becomes trade winds. Some of it flows out in the opposite direction, and blows toward the poles. As the air moves along in the northern hemisphere, it is turned toward the right and becomes the *prevailing southwesterly wind*, which flows across most of Canada and the United States.

Just as the air is heated and is forced upward at the equator, so it is cooled and sinks at the poles. Thus, at the poles, there are high pressure areas from which the cold air flows outward. Because this cold air is turned toward the right in the northern hemisphere, it becomes the cold *polar easterly wind.*

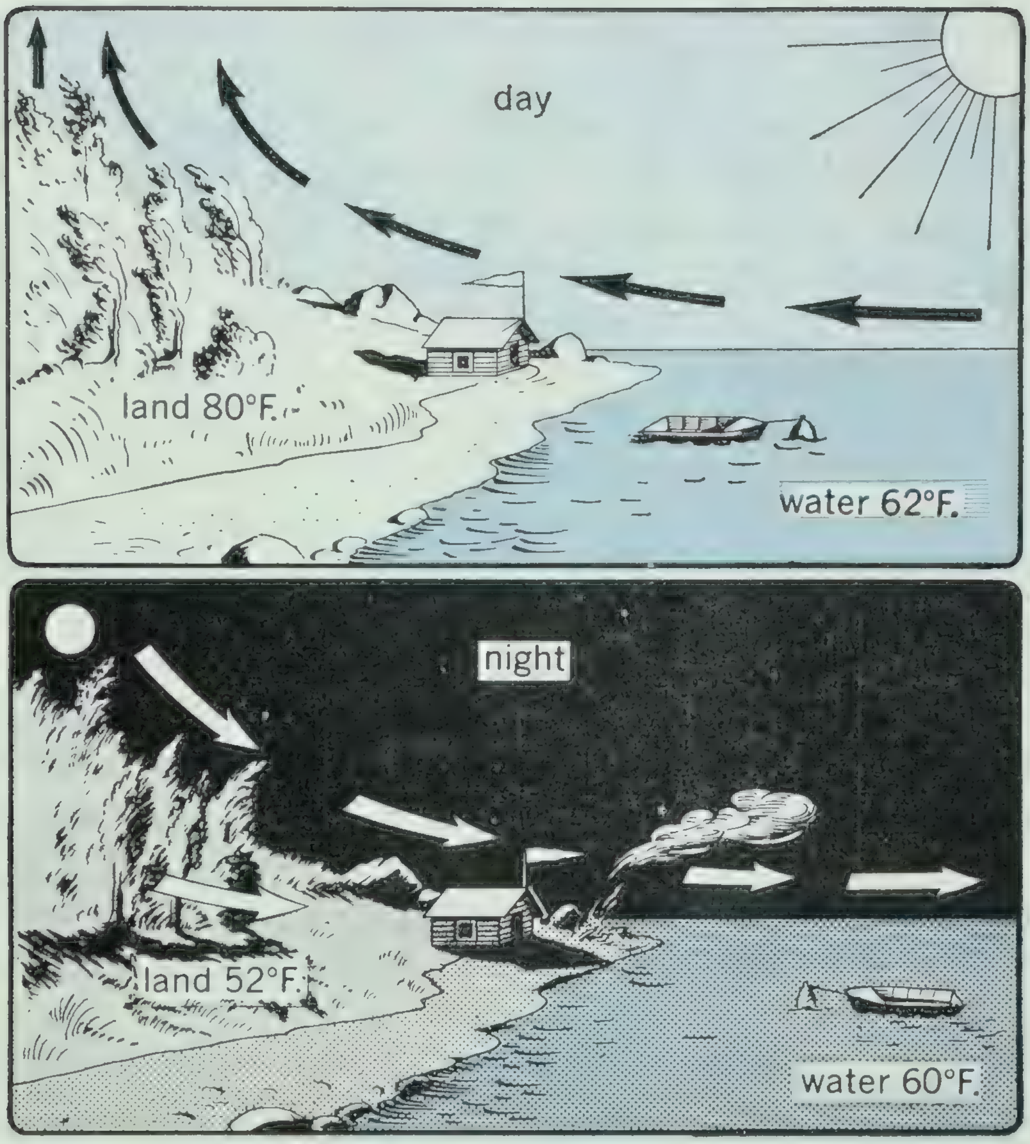
By studying the wind maps, you can see how, in the southern hemisphere, the prevailing northwesterlies and polar easterlies are caused.

In each hemisphere, where prevailing westerlies meet the polar easterlies, there is a low pressure area. Here the air is forced upward. High above the earth it divides. Some of it flows toward the poles, and some toward the horse latitudes, where it again sinks to earth.

There are, of course, many other kinds of wind in addition to prevailing winds. Most of these winds are caused by the uneven heating of the air.

How heat is distributed by wind

As you have learned, the sun is our greatest source of heat. The heat from the sun travels through space to the earth in the form of radiant energy. A large part of the earth's surface, as you know, is covered with water, and water has a great capacity for absorbing radiant energy and storing it as heat. Therefore, the radiant energy striking the oceans, seas, and lakes is absorbed, and the temperature of the water is increased. In this way, large bodies of water become storehouses for much of the summer's heat. This



These drawings illustrate the cause of land and sea breezes. Study them carefully. Explain fully the reason why there is a breeze from the sea, or other large body of water, during the day. What causes a breeze to blow from the land to the sea at night?

heat is later radiated and has a moderating effect on the climate of near-by regions.

Now let us see what happens when radiant energy from the sun strikes land areas of the earth. Perhaps, on a hot summer day, you have walked barefooted on a beach over dry sand and noticed that the sand was much hotter than the near-by water. However, at night, the same sand may be cooler than the water.

On a hot summer day, the air over land masses is heated to a higher temperature than that over a body of water. The result is that air currents are set up, just as they were in your experiment. The cooler, heavier air from over the water flows in under the warm air over the land and forces it upward. This is a *sea breeze.* At night, the land loses its heat quickly, but water, having a greater capacity for storing heat, remains fairly warm. Therefore, at night, the movement of air is from the land to the sea. This is a *land breeze.* Study the illustration.

Large bodies of water are important climate regulators. Oceans, bays, and large lakes, during the summer months, store much heat, which is slowly given up to the air during the

winter. For this reason, the climate of land areas that are located near large bodies of water tends to be cooler in summer and warmer in winter than that of areas that are far inland.

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. What is wind?
2. Make a drawing to show the earth's wind belts.
3. Explain the cause of land and sea breezes.
4. Make a labelled drawing to illustrate an experiment to find out how winds are caused.

WATER AND WEATHER

You will certainly have observed that our weather is seldom exactly the same for two days in a row. Weather varies from day to day and from week to week. Some days it is rainy, other days foggy, and, in winter, it is often snowy. Where does the moisture come from to form the rain, the fog, or the snow?

Is there moisture in the air?

Perhaps in winter you have heard someone remark: "It isn't the fact that the temperature is below zero that makes the weather feel so cold; it's the moisture in the air." Is this statement correct? Is there moisture in the air? You can find out by performing the following experiment:

SOMETHING TO DO

Secure a shiny tomato-can. Fill it half full with cold water. Add ice or snow. In a few minutes, the temperature of the ice-water will be lowered many degrees below room temperature. Watch for the formation of a film of moisture over the surface of the can. Since water cannot pass through the material of which the can is made, where must this moisture have come from? Why *did* the water vapor condense and gather together as tiny droplets on the can?

Repeat the experiment, using a mixture of snow and salt in the can. Are the results the same as before?

A similar procedure takes place when dew forms on plants. On clear nights in summer, plants lose their heat quickly. When moisture-laden air comes in contact with the cool surface of the plants, the air is cooled, condensation results, and *dew* is deposited on the leaves. You should understand, therefore, that dew does not "fall" but is formed at the point where it is found.

If the temperature of the plants or the ground is below the freezing point (32° F.), the water vapor condenses as *frost*.

Hoar frost on trees turns our woods and parks into a winter fairyland. How is frost formed? (Bruce Pendlebury photo)

How does water get into the air?

Have you ever wondered why your mother's washing becomes dry as it hangs on the clothesline, or what happens to water left standing in a dish for several days? You probably know that water *evaporates* and becomes a gas called *water vapor.*

You have often seen water escaping into the air from a kettle of boiling water. If you look closely at the spout, you will not see any moisture close to the opening. The reason for this is that when water boils, it escapes as an invisible gas called *steam.* As the steam cools slightly, it forms a small cloud. However, the tiny droplets of water soon evaporate again and are mixed with the air.

Large quantities of water are evaporated daily from the surface of oceans, lakes, ponds, and the soil. The rate of evaporation depends on the surface area, the temperature, the dryness of the air, and the rate of movement of the air. On what kind of day does your mother's washing dry most readily?

All the moisture in the air is not the result of the evaporation from bodies of water. There is some moisture that enters the air as a waste product of the process of respiration in plants and animals. You have, no doubt, breathed against a cold window-pane and observed the moisture from your breath that condensed upon it.

If a leaf of a plant is placed in a clean, dry test-tube, and the mouth of the tube is then plugged with cotton batting, you will soon notice tiny drops of moisture on the inner side of the tube. Try this experiment yourself. The test shows that leaves give off water into the air. The process is called *transpiration.* By this method, an acre of wheat will transpire about 600 tons of water during its growing period.

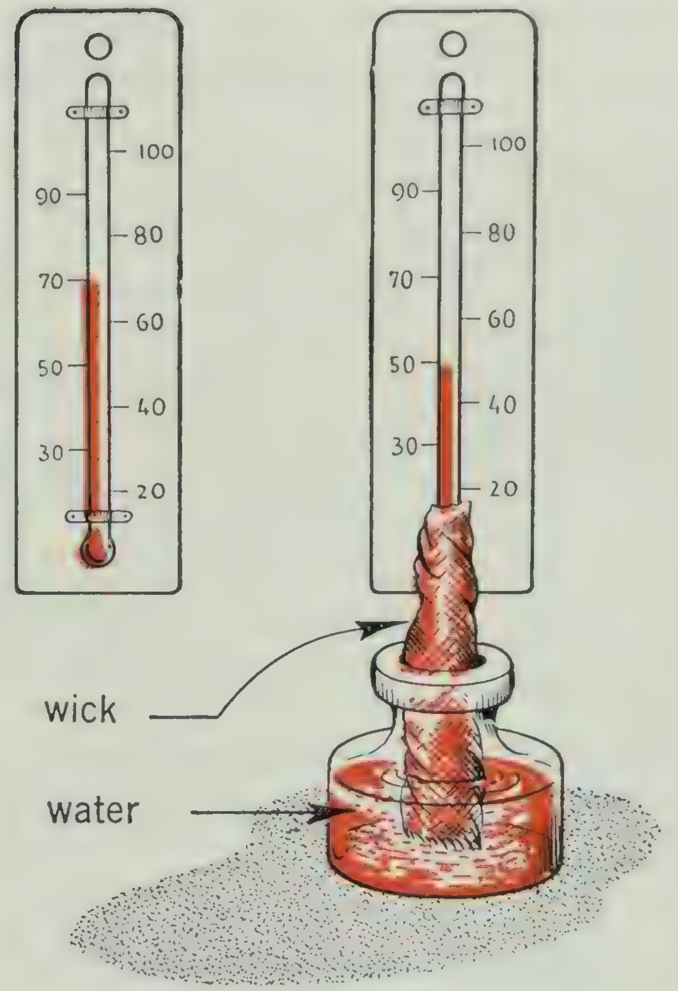
Relative humidity

Have you experienced a day in summer when you perspired freely even though you were just sitting still? On such a day there is usually a large amount of moisture in the air, and we say that the *humidity* of the air is very great. Humidity is the water vapor present in the air.

To measure humidity, we compare the amount of water vapor actually present in the air with the amount of water vapor that the air would be capable of holding at that temperature. This comparison is known as *relative humidity.* For convenience, relative humidity is usually expressed

in per cent. If the air is *saturated,* that is, if it contains all the water that it can hold at that temperature, its relative humidity is 100 per cent. If it contains only half as much water as it is capable of holding at that temperature, its relative humidity is 50 per cent.

The proper ventilation of homes, schools, theatres, and other buildings is important for our comfort and welfare. For healthful living, the relative humidity of our homes should be from 40 to 50 per cent. You can find the relative humidity of your home or school by performing the following experiment:



A drawing of a hygrometer used to measure humidity. This one consists of two thermometers, one having a wet bulb and the other a dry bulb. Explain why the reading of the thermometer with the wet bulb is lower than the one with the dry bulb. How can this apparatus be used to find the relative humidity?

SOMETHING TO DO

1. Construct a wet-and-dry-bulb hygrometer and use it to find the relative humidity.

Materials Required. — Two Fahrenheit thermometers which read the same; a small clean bottle (an ink bottle); a lamp wick or a strip of porous cloth; a board upon which this apparatus may be mounted; water.

Construction. — (1) Study the illustration at the top of this page. (The two thermometers may be mounted on a board about 12″ × 6″ × 1″.) The bottle (and board) may rest on a table. (2) Wrap the wick or piece of old dish towel (cotton or linen) tightly around the bulb of one thermometer. Tie a string around the bulb in order to hold the cloth in place. (3) Fill the bottle with water. (4) Drop the free end of the cloth or wick into the water.

Method and Observation. — (1) Fan the apparatus vigorously for two or three minutes before taking readings. (2) Read the temperature as shown by the wet-bulb thermometer. (3) Read the temperature as shown by the dry-bulb thermometer. (4) Calculate the difference between the two readings. (5) Refer to the table on page 312, and determine the relative humidity of the air. (6) Take readings daily, and keep a record of the relative humidity for a period of two weeks or longer. (7) Add more water to the bottle from day to day, or as it is required to keep the wick wet.

Conclusion. — 1. What is the relative humidity of the air as found by your experiment?

TABLE FOR USE WITH WET-AND-DRY-BULB HYGROMETER

DEGREES. . . of Difference in Temperature on Dry-bulb and Wet-bulb Thermometers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Reading of Dry-bulb Thermometer	Relative Humidity in Per Cent														
63	95	89	84	79	74	69	64	60	55	51	46	42	38	33	29
64	95	89	84	79	74	70	65	60	56	51	47	43	38	34	30
65	95	90	85	80	75	70	65	61	56	52	48	44	39	35	31
66	95	90	85	80	75	71	66	61	57	53	49	45	40	36	32
67	95	90	85	80	76	71	66	62	58	53	49	45	41	37	33
68	95	90	85	81	76	71	67	63	58	54	50	46	42	38	34
69	95	90	86	81	76	72	67	63	59	55	51	47	43	39	35
70	95	90	86	81	77	72	68	64	60	55	52	48	44	40	36
71	95	91	86	81	77	72	68	64	60	56	52	48	45	41	37
72	95	91	86	82	77	73	69	65	61	57	53	49	45	42	38
73	95	91	86	82	78	73	69	65	61	57	53	50	46	42	39
74	95	91	86	82	78	74	70	66	62	58	54	50	47	43	40
75	95	91	87	82	78	74	70	66	62	58	55	51	47	44	40

2. Investigate the methods being used to increase the humidity in homes and other buildings in winter. Why do many furnaces have pans for water?

Have you ever placed a drop of gasoline, alcohol, or water on your hand and allowed it to evaporate? When a substance changes from a liquid to a vapor, heat is absorbed. Some of this heat is taken from your hand, leaving it cooler than before. The drier the air, the more rapid the evaporation, and consequently the greater the cooling effect. This is the principle used in the wet-and dry-bulb hygrometer, one bulb of which is encased in a wick through which water is raised and evaporated. If there is very little moisture in the air, the evaporation will be rapid, and the cooling effect on the wet bulb will

be great. Hence the difference in the readings of the two thermometers will be many degrees, indicating that the relative humidity is very low. (Study the table on page 312.) On the other hand, when the air is moisture-laden, evaporation is slowed up, resulting in a lessening in the cooling effect on the wet bulb. The difference in the readings of the two thermometers will then be small, and hence a high relative humidity will be indicated.

The relative humidity of the air has an important bearing on weather conditions. When humid air is cooled, moisture will condense into clouds, fog, dew, or frost. The formation of rain or snow is a complicated process that will be briefly explained in a later section of this chapter.

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. Describe an experiment that you performed to find out if there is water in the air.
2. How would the rate of evaporation of water be affected by increasing (1) its surface area, (2) its temperature, (3) the rate of movement of air over the water, (4) the moisture already present in the air?
3. Devise experiments to check your opinion concerning at least two of the factors mentioned in question 2, and try them out. How many of these factors could you test in a single experiment? Be sure to follow the scientific method of "controlling" all experiments.
4. How is dew formed?
5. What is frost?
6. What is humidity?
7. Explain what is meant by relative humidity.
8. Describe an experiment to find the relative humidity of the air in your home or classroom.
9. What effect has relative humidity on healthful living?

CLOUDS AND THE WEATHER

Clouds are closely related to weather conditions. Indeed, people who know about the different kinds of clouds can often predict weather changes with surprising accuracy. You can learn to do the same. Some cloud formations are very beautiful. You may have tried to photograph some particularly fine cloud effects. By learning to appreciate the beauty of the clouds, you will be adding to your enjoyment of life.

How are clouds formed?

People who wear glasses usually find that when they enter a warm house or other building on a cold day their glasses cloud over so that they cannot see through them clearly. Have you had such an experience?

SOMETHING TO DO

1. Hold a cold plate in the steam coming from a kettle. What do you observe? How do you account for what you see?
2. Blow your breath against a cold window-pane or other clear, cold glass. What happens? Explain.

You will have observed that when the steam from a kettle or water vapor in your breath comes in contact with a cold object, a very fine film of liquid water is formed on the object.

Earlier in this chapter you learned that warm air is capable of holding more water than cold air can hold. The breath you exhale from your lungs is warm and moist. When this air comes in contact with the cold window-pane, the air is quickly cooled to the point where it cannot hold all the water vapor at that temperature. Some of the invisible particles of water vapor unite to form tiny droplets of water which are deposited as a film of liquid water on the window-pane.

Water vapor always condenses on a surface. In the air there are always present billions of very, very small particles of dust and smoke. Their presence in air can be noted in a beam of sunlight that enters a crack in a dark room. When water vapor changes back to liquid water, it forms around these tiny particles, and droplets of water result. These droplets are so small that it would take thousands of them to make one rain drop. Thus a *cloud* is formed. A cloud that is formed near the earth's surface is commonly called *fog*.

When is air saturated with water vapor?

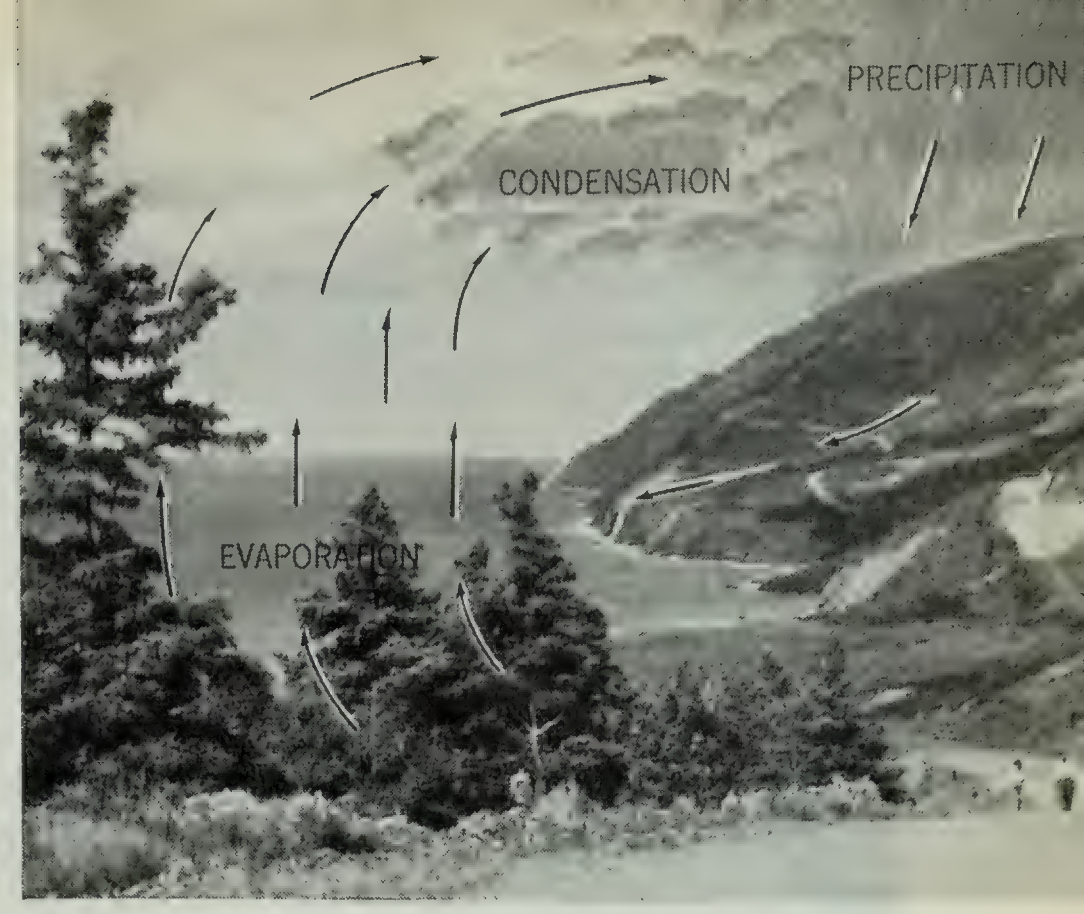
You have already learned that there is moisture in the air. Is there a limit to the amount of water that the air can hold?

SOMETHING TO DO

Fill a glass tumbler half full of water. Put a spoonful of common salt into the water and stir the mixture with a spoon. Does the salt disappear? Taste the water. Does it taste salty? You have made a *solution* of salt and water.

Continue to add salt to the water, a spoonful at a time, and stir the solution after each addition. You should soon reach the point when no more salt will dissolve. Your solution of salt and water is then known as a *saturated solution*. If more salt is added, it settles to the bottom of the tumbler as soon as you stop stirring.

Just as water dissolves salt to form a solution, so, too, the air is capable of dissolving water vapor, which, like the salt, becomes invisible. As has already been stated, warm air will hold more water vapor than cold air



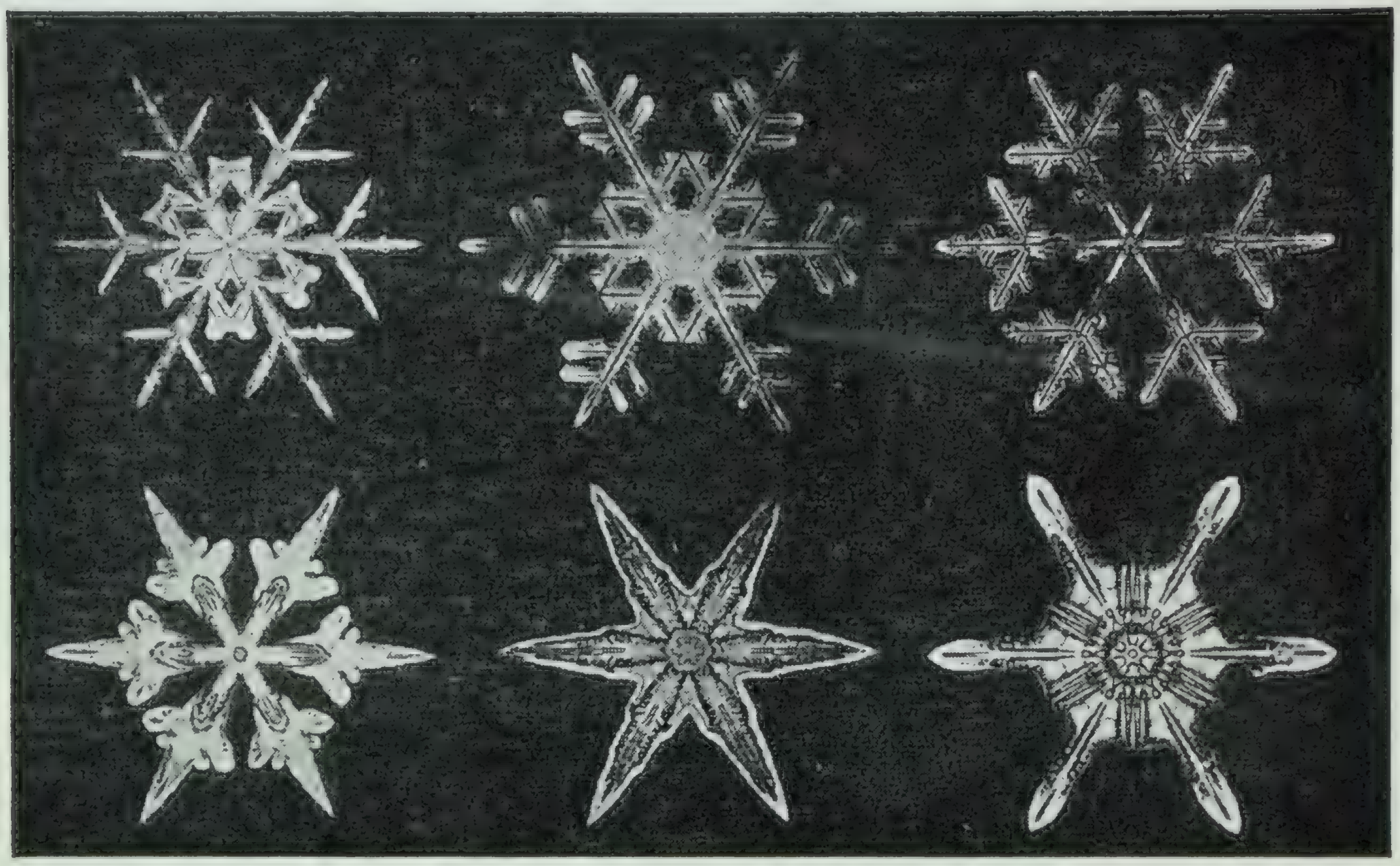
The water cycle. Follow the arrows around the cycle. Water evaporates from the ground, from trees and other plants, and from bodies of water. Why does this water vapor condense to form clouds? What causes precipitation in the form of rain, hail, or snow? How does the water get back to the sea? (Federal Government Travel Bureau photo)

will. Therefore, if moist, warm air is cooled, the point will soon be reached where the air is holding all the water vapor it can hold at that temperature. In other words, the air is *saturated*. If further cooling takes place, the invisible particles of water vapor unite to form tiny globules of water. This process is known as *condensation*.

There are several ways in which moisture-laden air may be cooled below its *saturation point* and result in cloud. First, when a current of warm air meets a cold one, the former, being lighter, is forced upward over the latter and is thereby chilled. Second, when warm, humid air is carried aloft by rising air currents, or moves up a mountain side, it soon reaches an altitude of greatly diminished pressure (see illustration on this page). The air expands and rapidly cools. Third, chilling of the air results if a warm air current passes over a cold region. If, in any of these cases, the air is cooled until it becomes saturated, further cooling will cause condensation; that is, some of the water vapor of the air will form into tiny droplets of liquid water. This collection of tiny droplets of water is known as cloud. Sometimes it is so cold that the droplets freeze, forming cloud composed of ice crystals.

How cloud changes to snow or rain

It is an interesting fact that even on hot summer days the temperature at the top of a cloud is often below the freezing point. This part of a cloud often contains tiny ice crystals and *supercooled* droplets of water that remain as a liquid in spite of the low temperature. When unfrozen droplets touch an ice crystal, they are joined to it, making the crystal larger and heavier. Air currents within the cloud may keep the ice crystal circulating for a long time. Finally it becomes heavy enough to fall out of the cloud. In winter, it falls as



Snowflakes are of many different forms. How many main points has each flake? Each snowflake is composed of very many ice crystals. (United States Weather Bureau photo)

a snowflake. However, in warmer weather, it melts as it falls, becoming a water drop that arrives at the earth as a drop of rain.

Scientists who study the weather have found that in Canada most of our rain is formed in the way described above. Sometimes, however, in thunderstorm clouds there is enough violent motion of the air to cause small droplets to join with larger ones until they become heavy enough to fall. Sometimes droplets of different sizes also join together in layer-type clouds and fall as a *drizzle,* or shower of tiny raindrops.

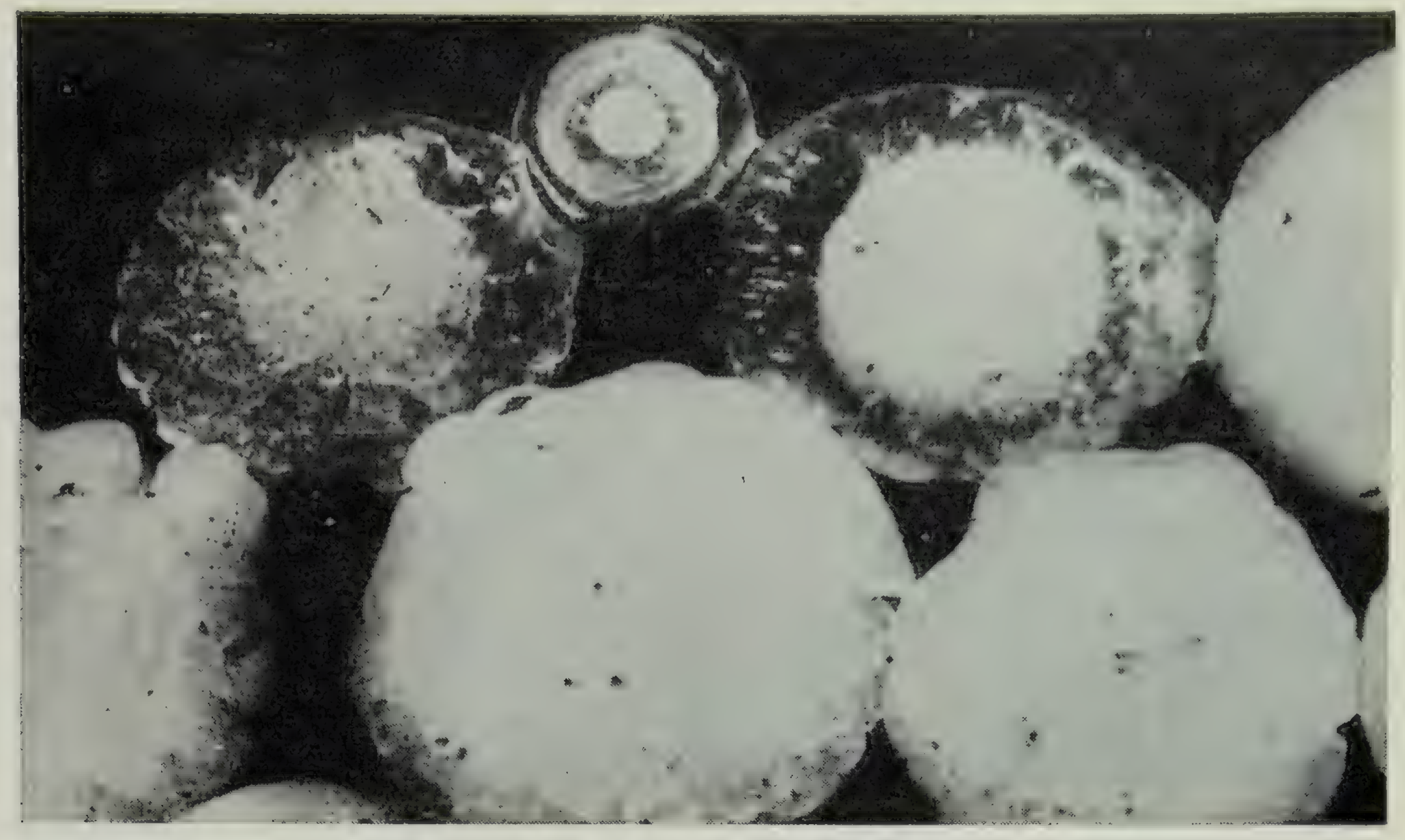
SOMETHING TO DO

On a day in winter when snow is falling gently, catch a few flakes on a black cloth, and examine them under a magnifying glass. See how many different patterns you can find.

Rainfall is of great importance to both plants and animals, as is indicated by the absence of forests and the scarcity of other forms of vegetation in dry regions; and where there is little plant life, there are few animals. The best of soil is unproductive unless it is well watered. Dry regions are, therefore, never densely populated.

How is hail formed?

Hail is perhaps the most spectacular form of precipitation. At times it is very destructive, especially to standing grain, gardens, and young



These hailstones, which fell in a hailstorm causing severe crop damage, are shown actual size. Smaller hailstones are more common than the ones shown here. The top hailstones have been cut in two to show rings of snow and ice that are always to be found in large hailstones. (United States Weather Bureau photo)

poultry, as well as to hot-houses and other exposed glass. Hailstorms usually occur in hot weather in connection with thunderstorms.

Hail consists of lumps of ice called hailstones, which usually have a snow-like centre, surrounded by layers of clear, hard ice alternating with snowy layers, as shown above.

Sometimes on hot summer days, precipitation takes place in the form of snow in the high atmosphere where, even on such days, the temperature is below freezing point. In its fall earthward, the snow may meet a warm, rising air current, which carries it back through the rain cloud to the higher, colder altitude. On passing through the cloud, the developing pellet collects water on its surface, which freezes into a layer of ice to which a coating of snow becomes attached. Again falling to a lower level, the pellet adds a layer of water, and then is caught in another up-rushing current and carried aloft to repeat the process. If this occurs many times, the pellet grows larger and larger until finally the current can no longer hold it up, and it comes crashing to earth as a hailstone. Most hailstones do not exceed half an inch in diameter, but stones many times this size have been reported.

A hailstorm is usually confined to a rather narrow strip, though it sometimes travels for a hundred miles or more.

Hailstorms often destroy crops, kill farm poultry, and damage buildings and other property. This automobile was wrecked after a ten-minute pounding by hailstones. What is hail and how is it formed? (United States Weather Bureau photo)

SOMETHING TO DO

1. Farmers raising crops such as wheat and tobacco, owners of greenhouses, and others whose livelihood could be destroyed by hail often insure their crops and buildings against loss by hail. Find out the cost of hail insurance in your locality. How are hail insurance rates determined?

2. If an opportunity presents itself, examine a hailstone to find the layers of ice and snow of which it is composed. Try cutting it in half with a sharp knife. Hailstones with as many as twenty concentric layers have been recorded. How many can you find?

What clouds tell us about weather

Have you noticed that sometimes the clouds overhead are light and fleecy and drift along quite lazily, while at other times they appear dark and threatening and move across the sky at a high speed? Some cloud formations are very beautiful. It should be interesting for you to be able to recognize the common types.

SOMETHING TO DO

1. Look for the common types of clouds for several days in a row. Make sketches of what you observe and compare them with the illustrations of cloud types shown on pages 320 and 321.

2. Observe the weather changes that accompany the appearance of the different kinds of clouds or that follow soon after the clouds appear.

3. Take pictures with your camera of the different types of clouds and of any unusual cloud formations that you see.

Curled, tufted, or featherlike clouds that appear very high in the sky, usually six miles or more above the earth, are known as *cirrus clouds.* Sometimes they are called *mare's tails.* They are composed of tiny

crystals of ice and always look white. Quite often, rainy weather follows the appearance of cirrus clouds.

Cumulus clouds are big, fluffy, white masses that look like huge piles of cotton or wool. They have rounded or dome-shaped tops and flat bottoms. They are fairly close to the earth; their tops extend upward only about a mile. True cumulus clouds develop on days of clear skies. They may develop into thunderheads which are the forerunners of thunderstorms. Cumulus clouds are caused by warm air being forced upward by cool air moving in underneath. If this warm air contains enough water vapor, the clouds build up into mountains of condensed vapor and produce thunderstorms.

Stratus clouds are also low-lying clouds. Long, even, and grey in appearance, they cover a large area and often appear to be in layers.

Nimbostratus clouds are heavy black storm clouds from which rain or snow is falling. *Nimbus* means rain cloud.

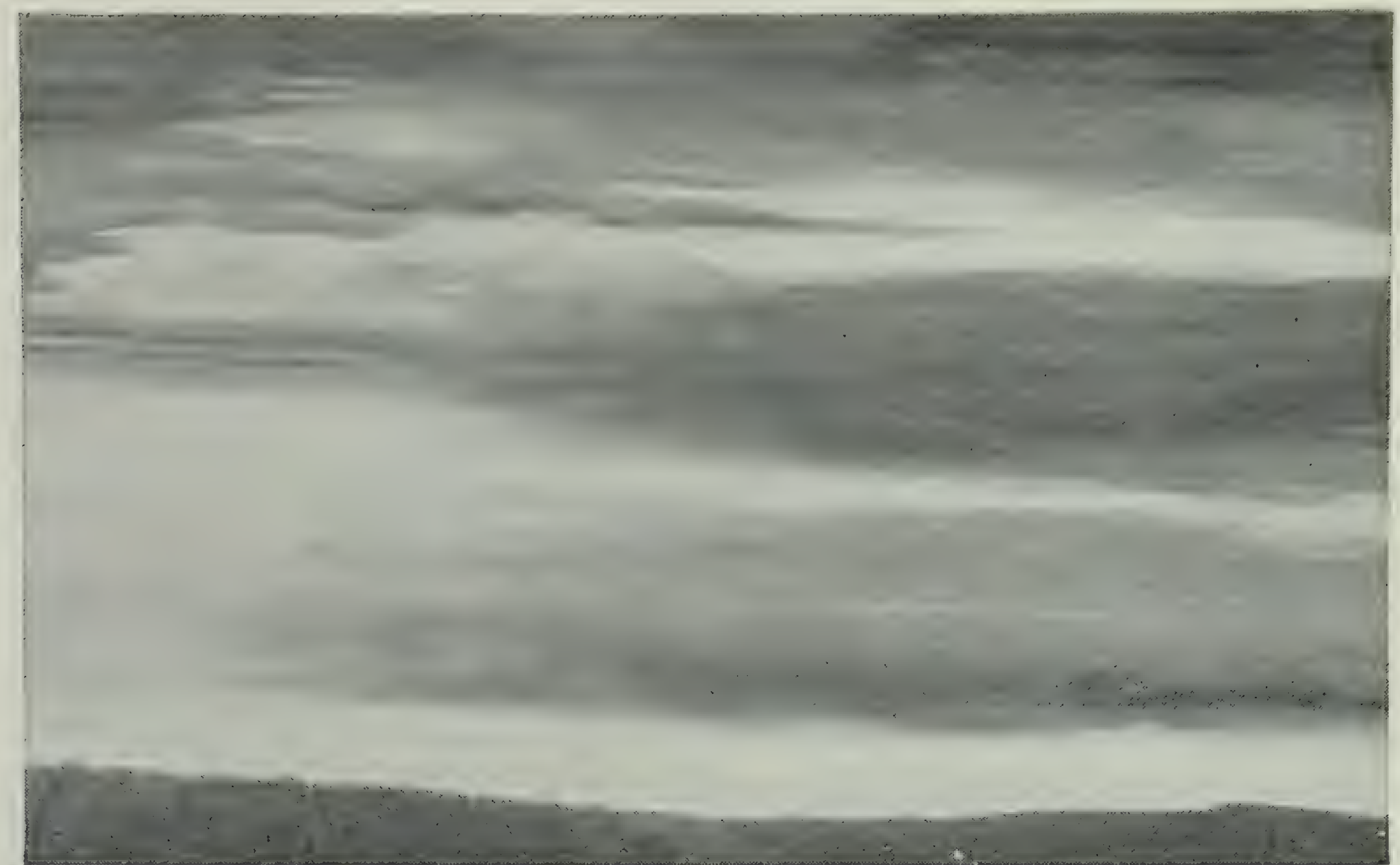
At times there may be several kinds of clouds in the sky at once. Also, clouds are not always of one of the four types mentioned here. There are various combinations of them. However, if you can learn to recognize the four common types, you will have made a good beginning in your study of clouds.

By accurate observation and knowledge about the different kinds of clouds, one can often foretell thunderstorms and hailstorms in summer and snow-flurries in winter. Air crew members, fishermen, farmers, and others whose occupations are directly affected by weather conditions are usually skilful in recognizing cloud forms and in using their knowledge to forecast weather changes.

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. How does temperature affect the water-holding capacity of the air?
2. When is the air said to be saturated with water vapor?
3. Explain how clouds are formed.
4. What is fog?
5. Mention three ways in which the air may be cooled below its saturation point.
6. Explain how water vapor changes to rain.
7. How is snow formed?
8. How does the structure of a hailstone help to tell us how it was formed?
9. Describe or sketch the appearance of the following types of clouds: cirrus, stratus, cumulus, and nimbostratus.
10. Tell how clouds help us to forecast the weather.

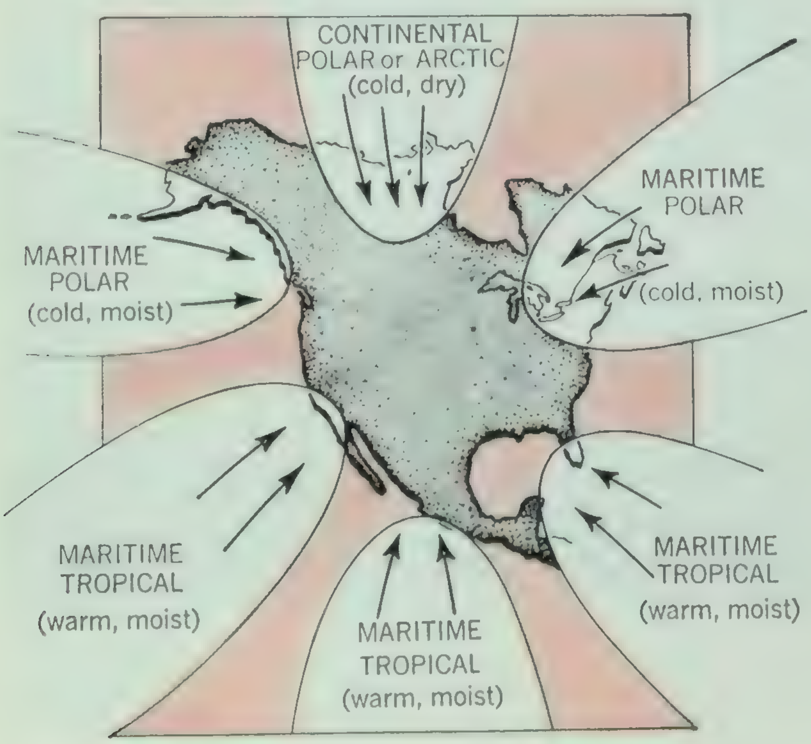
Top: Cirrus clouds. Sailors sometimes call these clouds "mare's tails." Bottom: Cumulus clouds. Note that they are nearly horizontal below, and piled up above. (United States Weather Bureau photos)



Top: Stratus clouds. Notice that these low-lying, long, grey clouds are arranged in layers. Bottom: Nimbostratus cloud. The nimbostratus cloud is a rain cloud. (Dominion Meteorological Service and United States Weather Bureau photos)

	TYPE OF CLOUD				
Wind Direction	Clear	Cirrus	Cumulus	Stratus	Nimbostratus
Northwest	clear	fair	clearing	clearing	showers, then clear
West	generally clear	increasing clouds	clearing	slowly clearing	showers, then clear
Southwest	increasing clouds	increasing clouds	possible showers	cloudy or stormy	stormy, then clearing
South	increasing clouds	increasing clouds	showers	cloudy, then stormy	stormy, then clearing
Southeast	increasing clouds	increasing clouds	probable showers	cloudy, then stormy	stormy
East	fair	increasing clouds	possible showers	increasing clouds	stormy, then cloudy
Northeast	clear	fair	clearing	cloudy	slowly clearing
North	clear	fair	clearing	slowly clearing	slowly clearing

A useful guide to tomorrow's weather, based on observations of clouds and wind direction. This guide is usually, but not always, accurate.



The movements of cold and warm air masses have important effects on our weather. This map shows the sources, direction of movement, and kind of air in the different types of air masses.

HOW SCIENTISTS FORECAST OUR WEATHER

Many kinds of activity, both business and recreational, depend upon favorable weather conditions. In recent years, new and improved methods of gathering weather facts have been put into effect. As a result, scientific weather forecasters are able to predict the weather with a greater degree of accuracy than was possible a few years ago.

Weather maps

In making his predictions about the weather, the forecaster makes extensive use of weather maps. You can learn a great deal about weather forecasts by studying such maps.

SOMETHING TO DO

Obtain copies of weather maps from the Dominion Meteorological Division, Department of Transport, 315 Bloor Street West, Toronto. When you write, ask for maps for three consecutive days. *Only one letter should be sent from each class.* The Dominion Meteorological Division will send to your class enough weather maps for each student. The class will also receive a number of large weather maps for your bulletin board, on which changes in the weather from day to day can be readily observed.

What information is shown on a weather map? Note the areas of low pressure and of high pressure. Follow the course of these pressure areas for three successive days. Try to predict where they will be on the fourth day. Note, too, lines marking "fronts" of advancing cold or warm air masses.

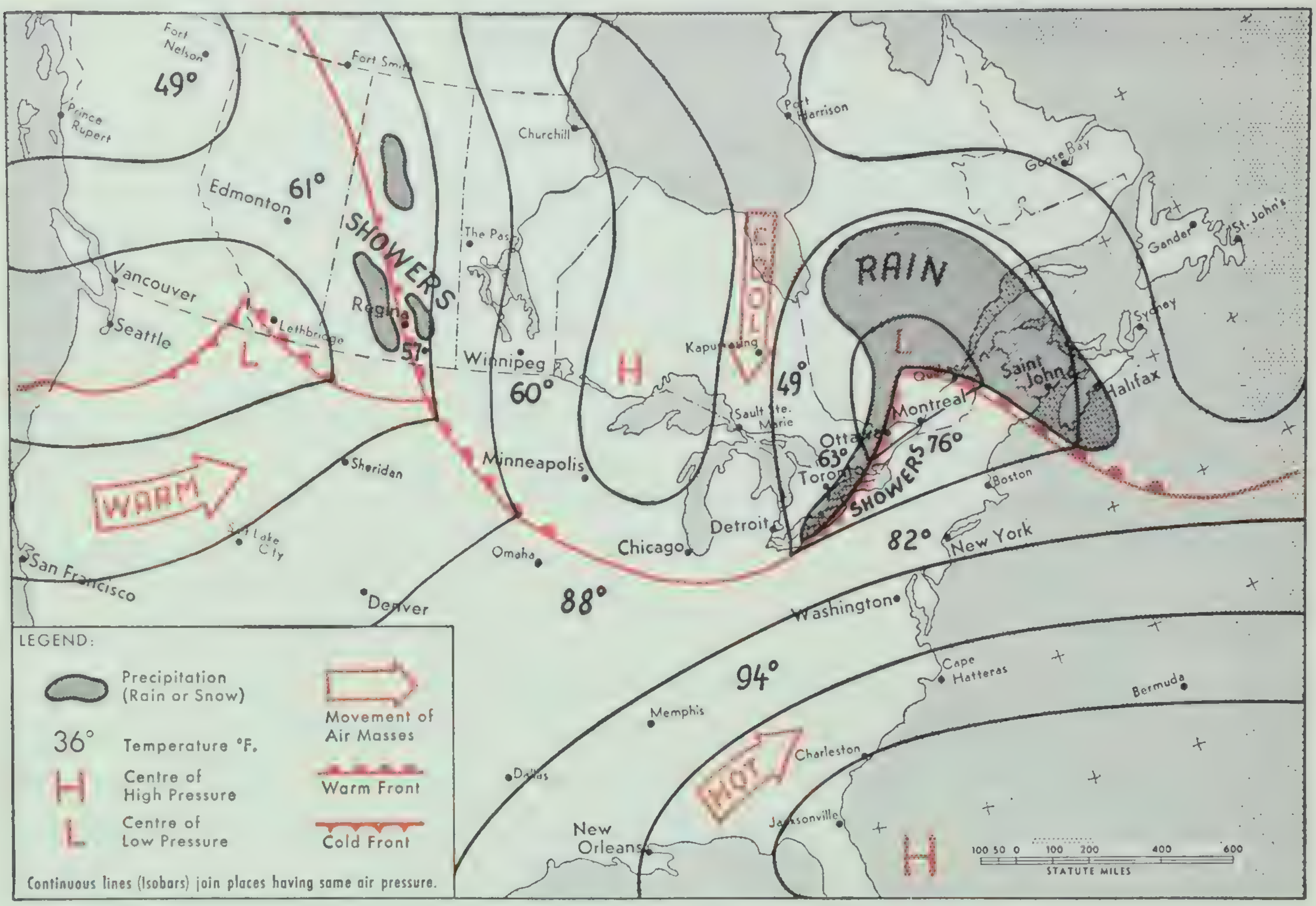
Scattered all across the North American continent and on islands in the Atlantic and Pacific Oceans are *weather stations*. Many of them are operated by the meteorological service of the Canadian government. The weather stations make observations every hour, or at least every six hours, of such weather facts as the following: temperature, air pressure, direction and velocity of the wind, condition of the sky (clear, cloudy), rainfall or other precipitation, and so on. This information is sent by teletype or by radio to the headquarters of the Dominion Meteorological Division and also to other centres where weather maps are issued.

Weather information is also received from ships at sea, and from airplanes over the ocean or high up over land. In addition, balloons carrying self-recording scientific instruments are sent aloft to great heights to gather important facts that help the forecaster predict weather changes with a high degree of accuracy.

As weather information is received, it is recorded on a weather map.

The movement of air masses influences the weather

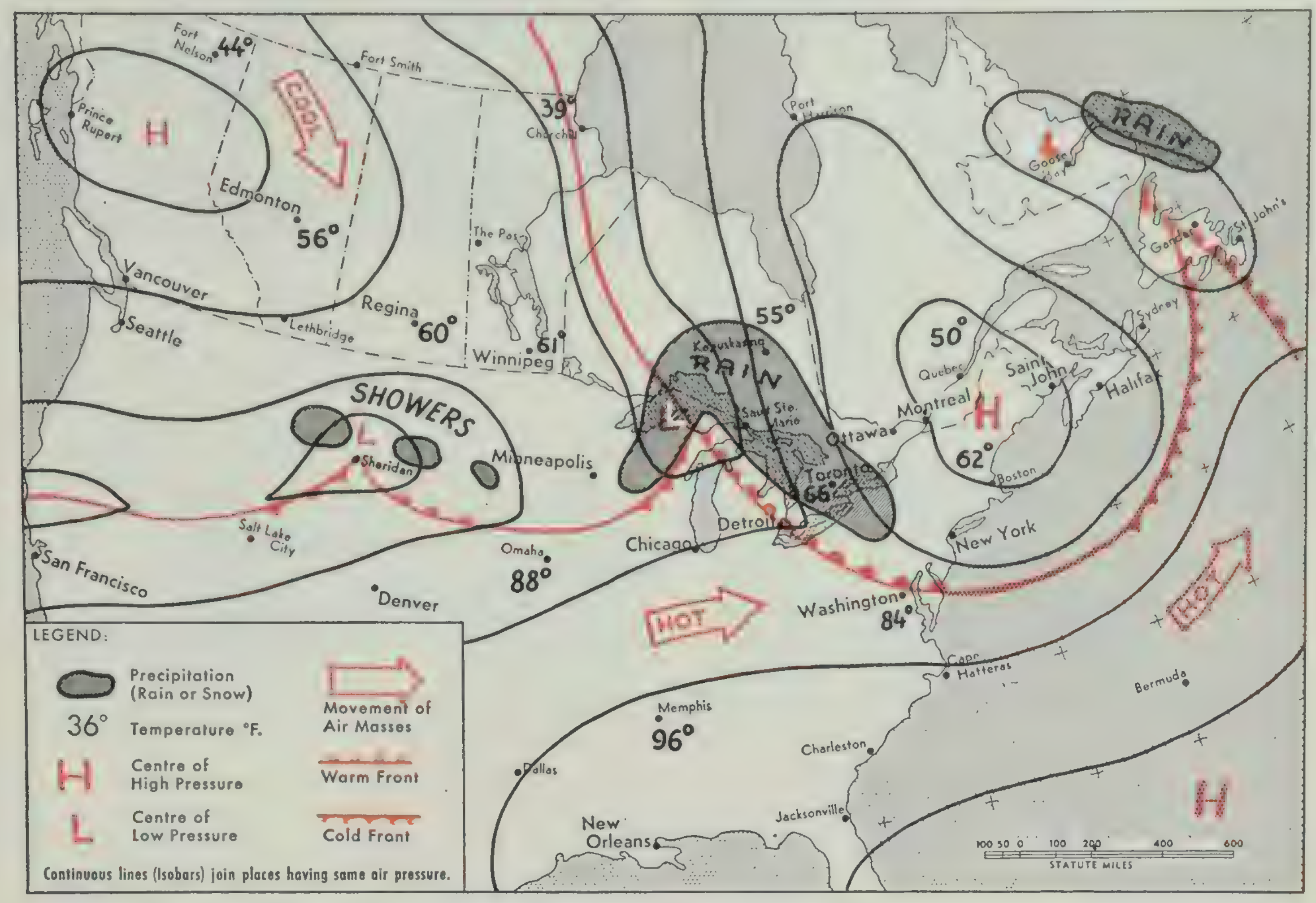
You will have read newspaper headlines such as *No Relief from Heat Wave in Sight* or *Cold Wave Grips Prairies.* Hot air waves and cold air waves are caused by the



On this and the following page are two weather maps that clearly show the weather across Canada for two successive days in August. Study these maps very carefully. On the weather map on this page find the following: (1) Two areas of high pressure, (2) two areas of low pressure, (3) two areas where rain is falling, (4) movements of cool, warm, and hot air masses. What is the effect of the cold air mass on the temperature in central Ontario? What is the difference in temperature on the two sides of the cold front in the Toronto-Montreal area? Tell as much as you can about the present weather conditions in Regina. (Original map courtesy Meteorological Division, Department of Transport)

movement of great masses of air across the country. An *air mass* consists of a large amount of air with uniform temperature and moisture which is spread over a wide area. Air masses are often several thousand miles across. If a warm, moist air mass moves over a section of Canada, the weather in that area will be warm and humid until the air mass is replaced by a cooler and drier one.

On the basis of where they originate, air masses that affect the weather in Canada are known as *Arctic, polar,* or *tropical.* The Arctic air mass develops in the northern Arctic regions. It is cold and dry. Polar air masses develop over the northerly regions of both eastern and western Canada. As Arctic and polar air masses travel in a southerly direction, they often bring cold air to southern parts of Canada. Tropical air masses develop over the Pacific Ocean and over the Caribbean Sea and the Gulf of Mexico. A tropical air mass is warm and usually



Study the changes that have taken place in the weather in one day. The areas of high and low pressure have moved eastward. Where is the area of high pressure that was over northwestern Ontario the day before? The warm front that brought showers to Saskatchewan has moved to the Great Lakes. Where is the area of low pressure and rain that was over southern Quebec and Ontario? What change has taken place in the temperature at Montreal? Account for this change. Tell as much as you can about the present weather conditions at Regina. Find a low-pressure area that has moved only slightly. Find a new air mass and a new pressure area that are affecting the weather in one part of Canada. What effect has this cool air mass had on the temperature at Edmonton? Where do you think that the new high-pressure area now over British Columbia will be in one day's time? (Original map courtesy Meteorological Division, Department of Transport)

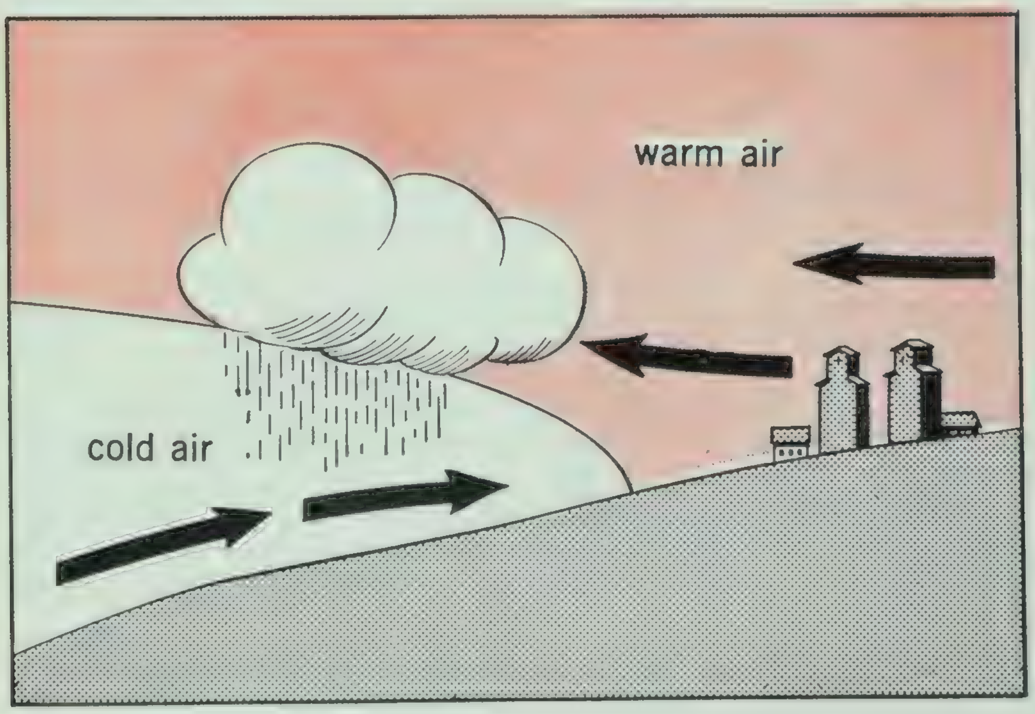
moisture-laden. As it moves in a northerly direction, it is likely to bring warm, humid weather, often accompanied by rain, to the areas along its path. It is usually a tropical air mass that causes hot, humid weather in Ontario in summer.

When cold and warm air masses meet, changes in the weather usually occur. For example, the warm, moist air may be forced upward, as the colder, heavier air flows in under it, as shown in the diagram on page 326. Explain what happens when the warm, moist air is forced upward.

You will now understand that the kind of weather we have depends to a large extent on where our air comes from and what has happened to it by the time it arrives in our part of Canada. Weather changes will be influenced by the season of the year, by mountains, large lakes, or oceans near our locality, and by other factors.

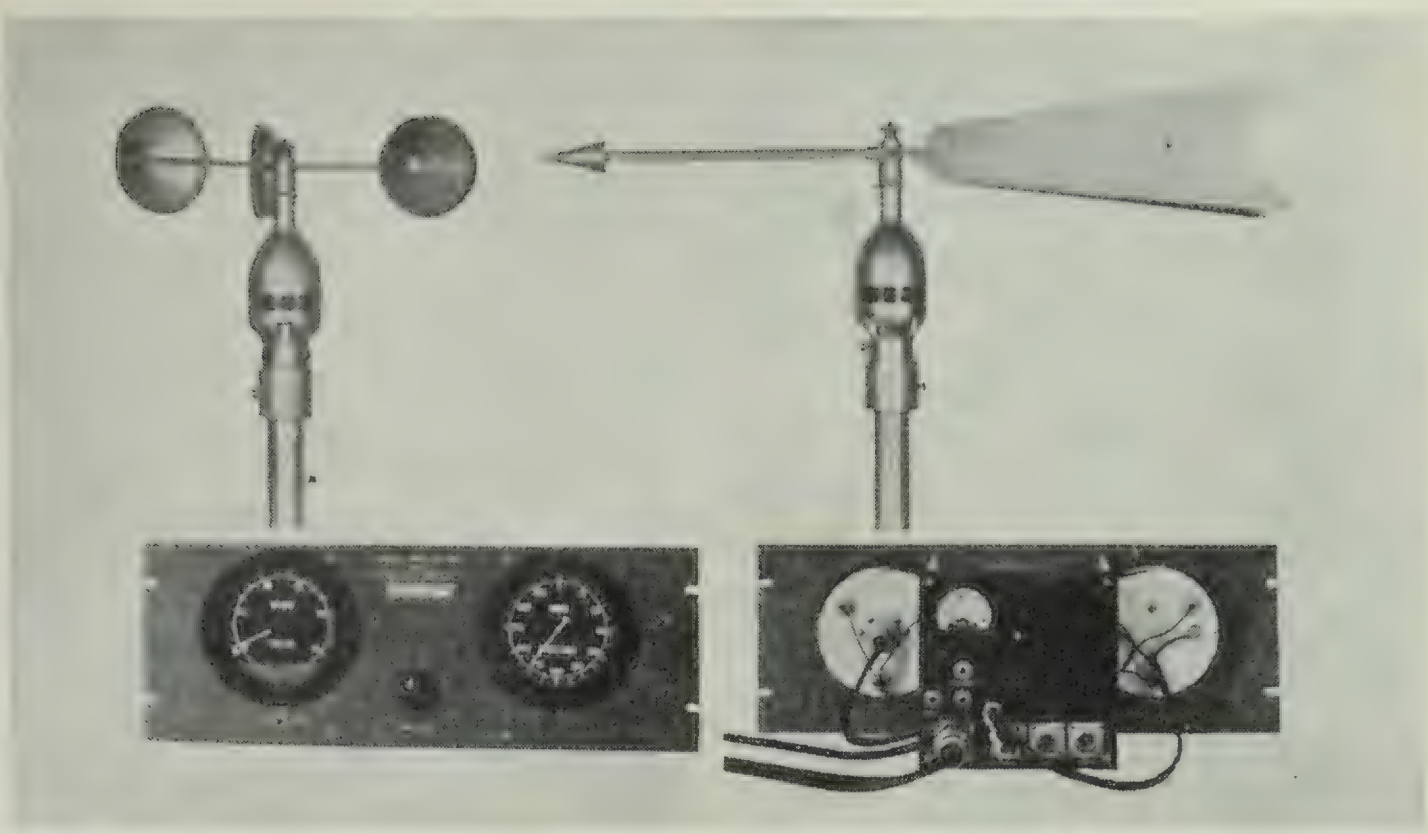
Forecaster entering weather facts on a map which will be used in forecasting the weather. (Dominion Meteorological Service photo)

Making observations at a weather station. The electric motor at the right ventilates the wet bulb of the hygrometer. The thermograph at the left traces changes in the temperature and tells when these changes take place. Note the maximum and minimum thermometers in horizontal position. Compare this photograph with the illustration on page 330. (Dominion Meteorological Service photo)



A warm air mass moving up over a cold air mass. Explain why there is likely to be precipitation under these conditions.

The Canadian weather ship St. Catherines occupies a station that is approximately 1000 miles west of Vancouver. One of its main services is to obtain weather observations from this remote area for the forecast offices of the Meteorological Service of the Department of Transport. (Dominion Meteorological Service photo)



Left: Anemometer for measuring wind speed. Right: Wind vane for telling wind direction. The anemometer and wind vane are located on top of a building, and are connected by electric circuits to recording instruments inside the building (see picture on page 289). (United States Weather Bureau photo)

A sunshine recorder. It keeps an automatic record of the hours of sunshine. (Dominion Meteorological Service photo)

Cold and warm fronts bring weather changes

The lines along which cold and and warm air masses meet are called *fronts.* Because the temperature and relative humidity in the air masses on the two sides of a front are quite different, many of our storms occur along fronts.

When a cold air mass pushes forward, its leading edge is called a *cold front.* If a cold air mass is retreating, and warm air is moving in to replace it, the leading edge of the warm air mass is called a *warm front.*

When a cold front passes, there is usually a change in wind direction. The temperature also usually drops as the mass of cold air moves in. The

warmer air is pushed upward by the heavy cold air. If the warm air mass is laden with moisture, rain or snow will probably be formed. However, if the warm air is dry, very little cloud and probably no rain will form as the cold front advances.Thus the weatherman must know what weather conditions exist ahead of the cold front so that he can predict the changes that the cold front will cause.

Similarly many factors affect the weather at a warm front. Often, as a cold air mass retreats, the advancing warm air flows up over it. If this warm air is very humid, rain or snow will probably be formed when the rising air is cooled. If the advancing warm air is dry, it may form only cloud as it pushes up over the retreating cold air. As a warm front passes, the temperature usually rises.

A third type of front is the *occluded front*. This occurs when a cold front catches up to a warm front. On a weather map these form a sharp point. You can see an occluded front over Newfoundland on the weather map on page 325. Find the warm front (marked with semi-circles) and the cold front (marked with triangles). By comparing this weather map to the one on page 324, you can see that the cold front has advanced farther than the warm front, and the angle between them is becoming quite small.

The weather that accompanies an occluded front will depend on the condition of the air in the different air masses. If the warm air mass is moist, it will be forced upward by the rapidly advancing cold front, and will probably form cloud, rain, or snow.

Weather forecasting is based on weather facts

When the positions of cold and warm air masses and the locations of cold fronts and warm fronts are marked on a weather map, the location of storms and areas of fair weather can be seen. By comparing successive maps, the path that a storm is following and the speed at which it is travelling can be determined. It is then possible for the forecaster to tell where the storm centre is likely to be one or two days later, and to predict the weather for the area over which it will then be passing.

The weather forecaster also makes wide use of his knowledge of air masses. He has to know about the air masses high overhead — where they are coming from and what changes will likely take place in them in the next few hours. He needs to know the speed, direction, temperature, and humidity of these air masses. To obtain this information, a *radiosonde* is used (see page 332). It is a small box containing a barometer, a thermometer, and a humidity indicator, and is attached to a balloon that carries it many miles above the earth. A small automatic radio transmitter sends readings of the temperature, air pressure, and humidity back to earth.

Radiosonde measurements are taken each day, and weather maps of the air are made for different levels above the earth's surface. In fore-

casting weather, air mass maps and regular weather maps based on ground level conditions are used.

Making the forecast

As you know, each of the weather stations across Canada measures weather conditions several times daily. These reports are wired to the Dominion Meteorological Division, and all the information for each station is marked on a large weather map. For each station is shown the temperature, barometer reading, wind direction and speed, precipitation, visibility, type and amount of cloud.

By joining together all the places with equal barometer readings, the weather forecaster is able to locate the centres of high and low pressure on his weather map. Then the cold and warm fronts are drawn.

With all this information on hand, the weather scientist is ready to make his forecast. By considering all the facts collected and recorded on the map, by observing the changes that have occurred since the previous map was made, and by using judgment based on his past experiences in weather prediction, the weatherman makes his forecast for the next day and perhaps for several days ahead.

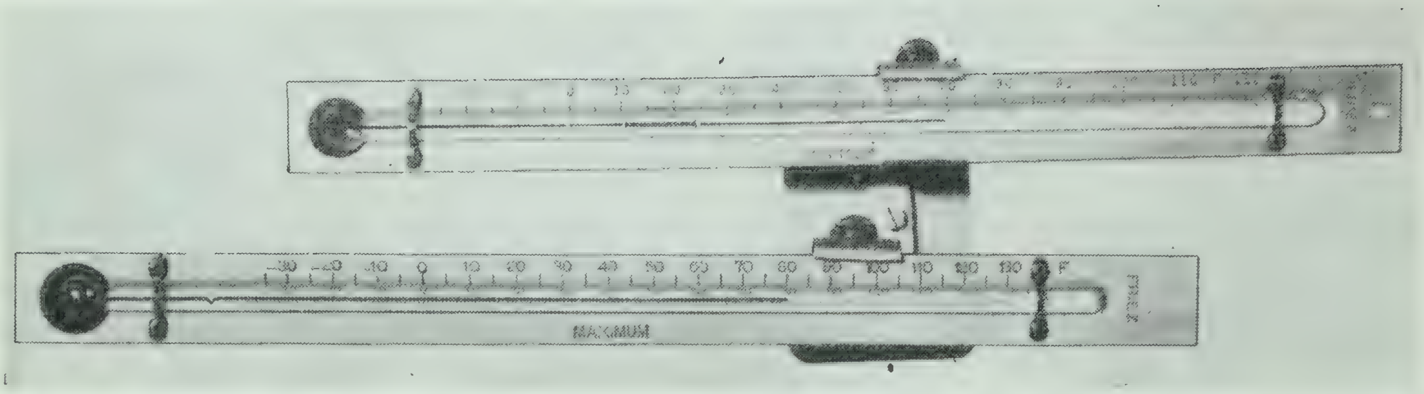
Watching for violent storms

At certain times of the year the weatherman must watch for conditions that might bring two violent

BEAUFORT WIND SCALE

Observation	Miles Per Hour	Term Used
Leaves still; smoke rises straight up.	0	Calm
Smoke moves; leaves flutter.	1-7	Light
Flags extended; twigs move.	8-12	Gentle
Small branches sway; dust and papers move.	13-18	Moderate
Small trees sway.	19-24	Fresh
Larger trees sway; it is hard to walk.	25-38	Strong
Twigs and branches break.	39-54	Gale

The most accurate way to measure wind speed is with an anemometer (see page 327), but you can estimate wind speed quite closely with this modified Beaufort wind scale, based on simple observations. Practise using this wind scale.



Minimum and maximum thermometers. In the minimum thermometer, the upper end of the small metal index shows the minimum temperature. On the thermometer above, the present temperature is 69°F., but the minimum for that day was 24°F. The maximum thermometer works like the clinical thermometer used by a doctor to take your body temperature. As the temperature rises, the liquid passes through a thin opening near the bulb. As the temperature lowers, it cannot go back through the small opening. Thus the maximum temperature for the day is shown. The liquid is shaken down to reset the thermometer. What was the maximum reading on the day this photograph was taken? (United States Weather Bureau photo)

kinds of storms – hurricanes and tornadoes.

Hurricanes are giant low pressure areas, often hundreds of miles wide, that begin in the tropics. They originate over the oceans, and in the northern hemisphere move northward. The winds in a hurricane often reach speeds of over 100 miles per hour, and do great damage to crops, forests, and buildings in their paths. In the southern United States, special weather services are maintained to watch for hurricanes, and warn the public if a hurricane proceeds toward land.

A tornado, or twister, is a funnel-shaped mass of air whirling very rapidly around a low pressure area (see page 336). Tornadoes appear to form along cold fronts where there is great difference of temperature. Tornadoes are usually only a few hundred feet in width, but wherever they touch the ground buildings explode and trees are uprooted. They occur frequently in the Mississippi Valley, but only rarely in Canada.

How accurate is the "weather man"?

Even with the aid of many scientific instruments, and weather facts from all over the continent and the oceans beyond, the meteorologist sometimes makes mistakes. It sometimes happens that unforeseen conditions develop and change the weather pattern that has been predicted. Have you heard people remark that, "The 'weather man' is usually wrong"? Is this a true statement? Make a check with your classmates to see how closely weather conditions correspond with those that were forecast.

SOMETHING TO DO

Compare weather forecasts with actual weather conditions for a period of at least 10 days. Daily comparisons for a month or more would be even better. Enter the information on a chart such as that shown on page 331.

WEATHER FORECAST RECORD

Date	Forecast	Actual Weather	Score		
			Mostly Correct	About Half Correct	Mostly Incorrect
Mar. 11	Temperature — low 12°, high 28°; wind NW 30 m.p.h., snow flurries	Temperature — low 10°, high 30°; wind NW 25 m.p.h., snow and drifting snow	x		
Mar. 12					

What conclusion have you reached? Why is it necessary to continue your observations for many days instead of for only one or two?

A school weather station

The pupils in Mr. Kennedy's class were becoming quite interested in the weather. Gordon Pearson reported that he had been at Victoria the previous summer, and had visited the weather station there. He told about the different instruments that were used to gather weather facts.

"Why couldn't we have a weather station here at school?" asked Peter Stevens. "We already have a *barometer* that we made. We could use it to find out what the air pressure is each day."

"That's right," said Lillian Dupont. "Also there's the apparatus that Bill and Tony made for finding the relative humidity."

"You mean the wet-and-dry-bulb *hygrometer*, don't you?" asked Bill.

"Maybe Gordon can tell us what other weather instruments we should have," suggested Betty MacDonald.

"Well, we would need a *wind vane* for telling wind direction, a *wind gauge* for finding the speed of the wind; and a *rain-and-snow gauge* for measuring rainfall and snowfall. I think we could make these instruments ourselves. We would also need a *thermometer* to take the temperature each day," answered Gordon.

"I suggest that we organize ourselves into a number of committees. Each committee could make one of the weather instruments and then use it to gather information about the weather," said Gary Fletcher.

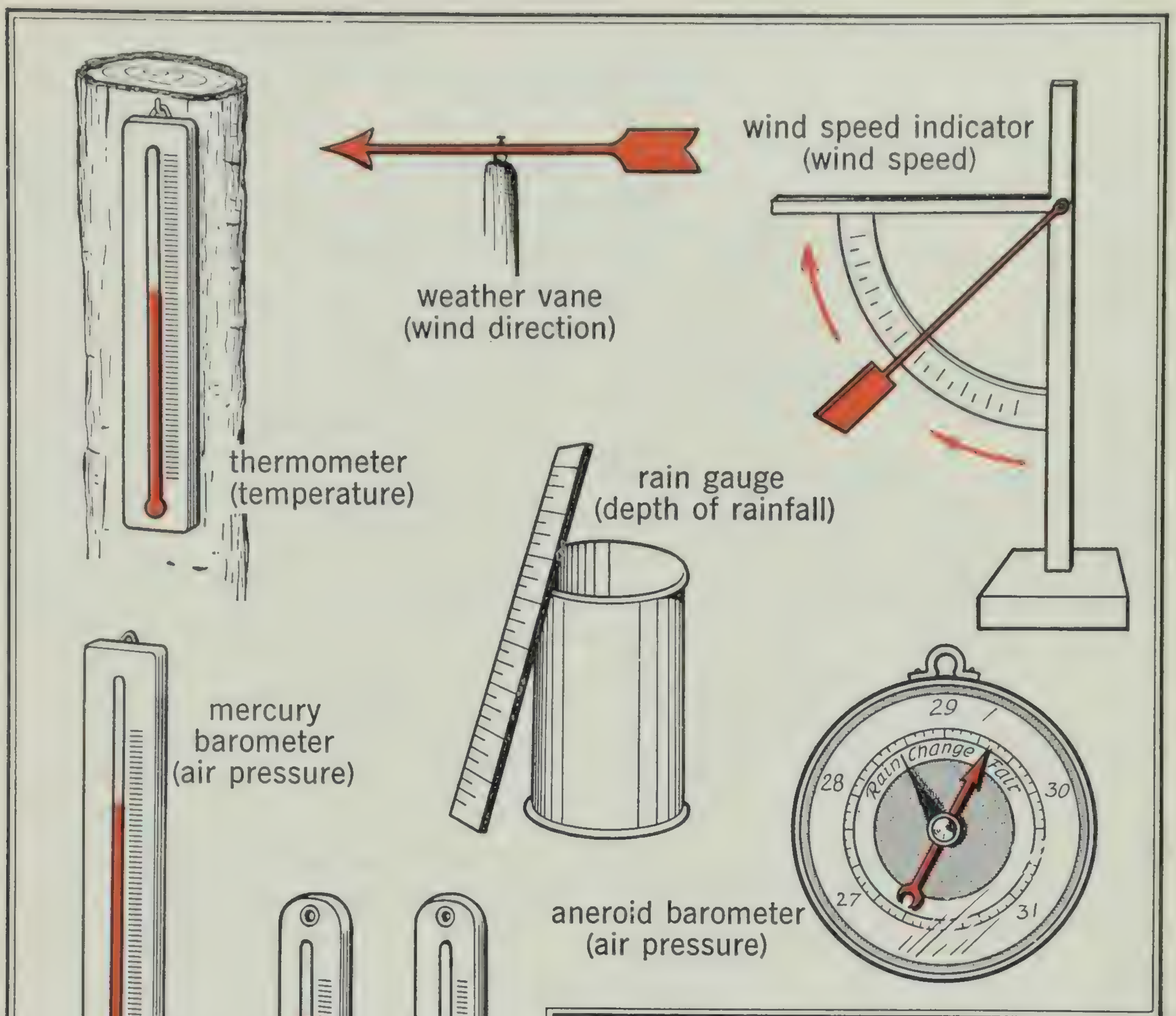
The weather observer at the right is preparing to release a radiosonde balloon, parachute, and instruments to learn about weather conditions high above the earth. He is holding the radiosonde in his hand. The observer at the left will follow the flight of the balloon by means of radar in order to determine the upper air wind directions and velocities. What weather facts does the radiosonde gather? How is this information sent to the weather station? (United States Weather Bureau photo)

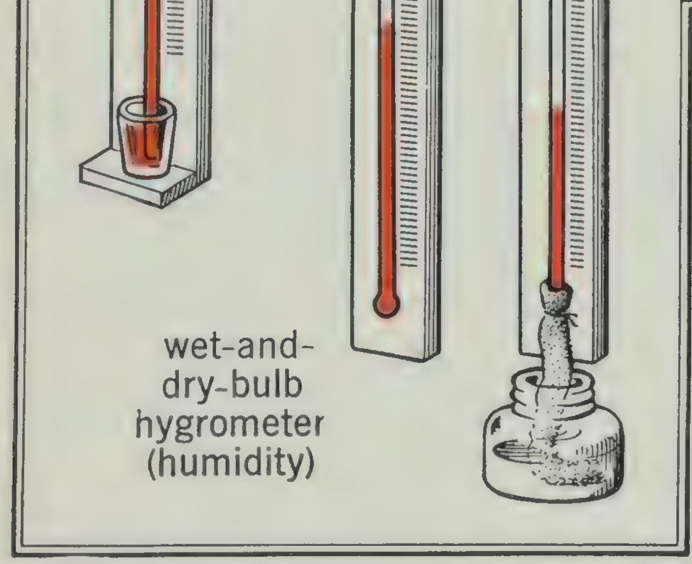
Gary's plan was accepted, and several pupils volunteered for the committees. The other members were appointed by Mr. Kennedy. The committees were soon at work gathering ideas about how to make simple home-made weather instruments. They found suggestions in science textbooks and other sources, and before long all the apparatus was assembled ready for use.

The class decided that observations should be recorded twice daily, at 9:30 A.M. and at 3:30 P.M. and continued for a period of three weeks. Observations of temperature and humidity were to be made out-of-doors and in the shade. All weather facts gathered were to be recorded in a table like the one on page 334.

SOMETHING TO DO

1. In your note-book, or on a blackboard or bulletin board, prepare a table like the one shown on page 334. Form committees to take turns in making weather observations. In the table, enter daily weather observations gathered at your school weather station.
2. On the basis of these facts, predict the weather for the following day and record your forecast in the table. (Keep in mind that a rising barometer generally means fair weather, while a falling barometer or low atmospheric pressure indicates changeable weather with approaching storms. Also, make use of your knowledge of the changes that can be predicted from cloud formations and wind direction.)
3. The day following each forecast, observe and enter the actual weather conditions on your chart.
4. Watch television broadcasts, listen to radio weather reports, and read forecasts in newspapers to learn more about the weather.
5. If there is a local weather station in your vicinity, visit it and ask an official to show you the instruments used to gather weather data.





Weather instruments for your school weather station. (1) Air pressure: Construct a mercury barometer, as described in some detail on page 301, and borrow an aneroid barometer. (2) Temperature: Hang a thermometer from the north side of a post in the open. Shield it from early morning and late afternoon sun. (3) Rainfall: Use a tall cylindrical fruit juice can with top removed, and a foot ruler. Set the can in the open, well away from trees or buildings. As soon as possible after the rain has stopped, use the ruler to find the depth of rainfall in inches. (4) Wind direction: Cut a wind vane out of wood. Find the point about which the vane balances. Using a nail and washers, pivot the vane at this point to the top of a post, so that it swings about freely. (5) Wind velocity: Construct a wind-speed indicator, as shown. The movable part must be free to swing. The stronger the wind, the higher the vane will swing. An anemometer similar to the one shown on page 327 can be easily made by attaching paper cups or funnels of aluminum foil to the ends of two small wooden cross-arms mounted so that they can turn freely in the wind. (6) Humidity: Construct a wet-and-dry-bulb hygrometer, as shown on page 311.

The Weather

What is it moulds the life of man?
The weather.
What makes some black and others tan?
The weather.
What makes the Zulu live in trees,
And Congo natives dress in leaves
While others go in furs and freeze?
The weather.

What makes some glad and others sad?
The weather.
What makes the farmer hopping mad?
The weather.
What puts a mortgage on your land
That makes you sweat to beat the band,
Or takes it off before demand?
The weather.

—*from Ways of the Weather by W. J. Humphreys*

WEATHER CHART

Date	Air Pressure (Barometer)	Temperature (Thermometer)	Relative Humidity (Hygrometer)	Wind Direction (Weather-vane)	Wind Speed (Wind Gauge)	Condition of Sky clear or cloudy; types of clouds	Precipitation (Rain or snow gauge)	Weather Prediction	Actua[l] Weath[er]
Mar. 18 9:30 A.M. 3:30 P.M.									
Mar. 19 9:30 A.M. 3:30 P.M.									
etc.									

Are weather signs reliable?

From earliest times, man has tried to foretell weather conditions. Some present-day forecasts made by people who lack scientific training in this field are based on definite observations and therefore may have value; others have no foundation in fact and are purely guesswork; still others are merely ancient superstitions.

Some statements about weather are given below. You may know others. Which do you think have value in weather forecasting? Which are superstitions? Give reasons for your answer.

1. If it rains before seven, it will clear before eleven.
2. Sunshine, shower;
Rain again in half an hour.
3. Rainbow in the morning, sailors take warning;
Rainbow at night, sailors delight.
4. The moon and the weather
May change together,
But a change in the moon
Does not change the weather.
5. Evening red and morning grey
Help the traveller on his way;
Evening grey and morning red
Bring down rain upon his head.
6. A winter fog will freeze a dog.
7. When the dew is on the grass,
Rain is not likely to come to pass.
8. If squirrels store a lot of nuts, we shall have a cold winter.

SOMETHING TO DO

1. Check the truth of these weather sayings by observing the weather that follows each of the conditions. For example, if it rains before seven, observe whether or not it clears before eleven.

2. Assuming that one day you checked as suggested in question 1 and observed that the weather cleared before eleven, would you be justified in arriving at the conclusion that the weather saying is correct? Why? If you are to follow the scientific method in making this investigation, what must you do?

Guide for amateur weather forecasters

The meteorologist who issues daily forecasts has a very great deal of information on which to base his prediction. However, you can learn to make some predictions with a fair degree of accuracy by making use of the following weather observations:

1. *Clearing weather*: rising barometer, clearing sky, falling temperature.

2. *Fair weather:* a slowly rising barometer or a high, steady barometer, white cumulus clouds or a clear sky, clear sunset and sunrise skies, heavy dew.

3. *Stormy weather:* a sudden drop in barometer readings, thickening cirrus clouds, forming of thunderheads or dark bases on cumulus clouds, chimney smoke travelling toward the earth, no dew.

4. *Colder weather:* wind shifting to north or west.

5. *Warmer weather:* wind shifting to south.

Of what value are weather reports?

The Dominion Meteorological Division was originally organized for the

A tornado, such as the one illustrated here, can be very destructive to life and property. Weather reports warn people about the approach of disastrous storms. (United States Weather Bureau photo)

purpose of warning fishing vessels and other small craft of the approach of violent and dangerous storms and gales. Such storm warnings are issued for the coast areas of the Atlantic and Pacific Oceans and also for the Great Lakes. A system of radio and television communication is used to spread the warning.

Storm warnings also aid land travellers. Storm warnings in winter, advising motorists to stay off the highways, are instrumental in preventing serious inconvenience and possible loss of life.

Weather reports are of vital importance to agriculture. "Cold wave" notices in late summer are signals to growers to harvest any crops that would freeze easily. For many years, an efficient frost-warning service has been maintained in Canada and the United States in fruit districts such as southern Ontario, the Okanagan Valley in British Columbia, and California. Citrus fruit crops to the value of millions of dollars have frequently been saved from ruinous loss when the growers heeded the frost warning of the forecaster and kept the orchard heaters in operation during the period of danger. The frost-warning service is also useful to truck-gardeners, as it enables them to protect tender crops, such as freshly set-out tomato plants, by covering them with soil, paper, or cloth. Earlier in the season, the minimum temperature forecast may assist them in regulating the temperature in their greenhouses overnight.

Weather reports warn farmers of approaching hot or cold waves, so that they can take proper precautions to protect shipments of perishable farm products, such as fruit, vegetables, and eggs, from damage caused by extremes of temperature, or so that they can avoid shipping live animals during very hot weather. Watermelon growers know that a sudden drop in temperature in cities cuts the demand for their product, and that if they are informed of the approach of cold weather, they can avoid loss by reducing the size of the their shipments. Similarly, manufacturers of ice cream try to regulate the amount of ice cream to suit the demand, which, in turn, varies with the temperature.

Scientific agriculturists have found that plant diseases and insect pests

are greatly affected by weather conditions. With weather forecasts available, outbreaks may be predicted, and control measures organized. Before spraying his orchard, a fruit-grower needs to know the wind velocity, and whether or not rain is likely to fall. Some poison sprays, for example, injure the foliage if applied when the leaves are wet, while other sprays can be applied advantageously only to wet leaves. Grasshopper poison should be spread only when the weather is favorable, that is, when the temperature in the shade is not less than 68 degrees Fahrenheit and not more than 90 degrees Fahrenheit, when the sky is clear, and when the plants are free from dew or rain. Forecasts of early fall frosts warn farmers to harvest their tobacco, tomato, and other crops before the crops can be damaged.

Efficient weather service is essential to the successful operation of air routes. Pilots depend on weather forecasts for information about fogs, low clouds, visibility, and direction and velocity of winds. They want to know, too, whether thunderstorms or sleetstorms are likely to be encountered along the proposed flight. It sometimes happens that a strong surface wind may be blowing in one direction, while, a few thousand feet up, the wind may be directly opposite; in such circumstances, it is to the advantage of a plane going in one direction to fly high and to one travelling in the opposite direction to fly low. Such information is regularly furnished to pilots on all organized mail or express routes.

Stores handling special lines of clothing, such as raincoats and rubbers, pay close attention to long-range weather forecasts and try to have a supply of goods ready to meet the demand.

Forest fires are known to occur under certain definite weather conditions; the Meteorological Division, therefore, is frequently called on to furnish forecasts to assist in reducing the forest fire hazard.

To all of us, weather forecasts are important in planning our day's activities. The clothes we wear, our method of travel, the out-of-door sports we engage in are all determined by the weather. We have become very dependent on the "weather man" in our daily living.

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. Name four scientific instruments used in gathering weather facts, and state what information is obtained from each.
2. Where, when, and by whom are weather observations made for the Meteorological Division?
3. Mention four facts about weather that are shown on a weather map.
4. Explain how the meteorologist makes his forecast.
5. What does a drop in the barometer reading indicate?

These interesting snow formations add beauty to this winter landscape. (T. R. Melville-Ness photo)

6. Of what value are weather forecasts to (1) shipping, (2) fishing, (3) aviation, (4) agriculture, (5) forestry? Give one or more definite examples in each case.

7. "Weather has an important effect on the life and work of the community, and on the health and happiness of the people." Explain.

WHAT HAVE YOU LEARNED?

IMPORTANT SCIENCE IDEAS AND UNDERSTANDINGS

A

1. Weather affects our manner of living in many ways.
2. Man has very little control over the weather, but he can adapt his activities to it.
3. Atmospheric pressure varies from day to day and from one locality to another.
4. The amount of water vapor that air can hold varies with the temperature.
5. The moisture in the air influences the weather in many ways.

6. Moisture comes out of the air as precipitation in the form of rain, sleet, hail, snow, dew, or frost.

7. Clouds are formed when the air is cooled below the saturation point.

8. The four main types of clouds are: cirrus, cumulus, stratus, and nimbostratus.

9. Cold air masses and warm air masses travel across Canada, bringing different kinds of weather with them.

10. At a weather station, various scientific instruments are used to measure and record different weather conditions, both at the earth's surface and high above it.

11. At a forecast centre, weather facts from many weather stations and from ships at sea are recorded on weather maps.

12. By studying weather maps, charts, and records, a forecaster can predict the weather quite accurately.

13. Foretelling weather by means of weather sayings is often an unreliable method.

14. Weather forecasts are useful in planning man's activities.

(a) The foregoing sentences are all true statements of important science ideas and understandings. Read and discuss them carefully as a review of this chapter.

(b) The following sentences describe situations in which some of these ideas apply. To test your ability to apply ideas to actual situations, match the sentences in A with the situations in B to which they apply.

B

1. On a cool day, Mrs. Goodman left her car standing for some time with the windows closed while she did some shopping. On returning to her car, she found that she could not see through the windshield, as it was clouded over on the inside.

2. When Charles Parker returned from school in the evening, the air was quite warm and the sky cloudy. However, by noon the following day, the temperature had dropped considerably, and the clouds had disappeared.

3. Walter Emery and his parents planned a motor trip to Winnipeg during the Christmas vacation, but due to a blizzard that blocked the highways, they were forced to change their plans.

4. On a day in summer when the weather was warm and dry, Yvonne Carter and her friend had fun during the day playing on

the lawn. However, when they went out again in the cool of the evening, they found that the grass was quite wet. No rain had fallen, and the lawn sprinkler had not been in use.

5. A heavy fog was covering a valley in early morning. Soon after the sun came out, the fog disappeared.

6. Ruth Kelly listened to the weather report on the radio, and then decided that it would be wise to wear her raincoat to school.

7. Paul Duchesne noticed his dog eating grass and remembered the weather saying: "Dogs eat grass before it rains." He therefore decided not to go on a picnic that had been planned. As it turned out, it did not rain after all, but Paul missed the picnic.

IMPORTANT SCIENCE TERMS

A

weather	condensation	nimbostratus
low pressure area	cloud	weather station
barometer	rain	hygrometer
air mass	hail	rain gauge
altimeter	snow	wind vane
sea breeze	dew	radiosonde
water vapor	cirrus	Meteorological Division
humidity	cumulus	weather forecast

To show that you understand and can use the science terms listed in A, match with the situations described in B those terms which apply.

B

1. The pilot of an airplane approaching a mountain checked his instrument carefully to make sure that the plane was high enough to clear the mountain.

2. When a warm air mass met a cold air mass, a cloud formed, and rain fell.

3. Information about air conditions high above the earth is obtained by means of a scientific instrument.

4. Donna Kubo made several observations out-of-doors: smoke was drifting earthward from a near-by chimney, the wind was blowing from the east, and the temperature was falling.

5. The boys made some apparatus for finding the amount of moisture in the air. On using it, they found that the relative humidity in their classroom was 50 per cent.

6. Frank Selby and a few friends were preparing for a bonfire on the beach. In the afternoon, they brought some logs for seats. Bill noticed that the wind was blowing from the lake. "Let's place the log on the side nearest to the lake," he said.

"If we do that," replied Ruth, "the smoke will blow in our eyes because by tonight the wind will be blowing the other way."

7. On the way to school, Linda Goodman and Betty MacDonald observed that the sky was full of billowy clouds with flat bottoms. They knew that the day was likely to be fair.

8. On the school field-day, the weather was warm and bright. However, both athletes and spectators perspired freely even when moving very little.

SCIENTIFIC METHOD AND ATTITUDE

1. The pupils in Mr. Kennedy's class were learning to follow the scientific method in solving problems. One day while discussing the process of evaporation, Mr. Kennedy raised the problem: *How does the surface area affect the rate of evaporation?*

Perhaps you can perform an experiment in school or at home to assist you in finding the correct answer to the problem raised by Mr. Kennedy. You might start with a container with a large area exposed to the air, such as a large glass mixing bowl, and another container with a small opening, such as a quart milk bottle. Pour a pint of water into each container. The water must be at the same temperature in each case. Set the bowl and the bottle side by side where they will be at the same temperature and where the air about each container will have the same relative humidity. Make observations in one day, in two days, and in one week.

(*a*) In this experiment, list the factors that were kept constant (the same).

(*b*) What factor was varied?

(*c*) Should the experiment be repeated several times before a definite conclusion is reached? Why?

2. One day in Mr. Kennedy's science class, the pupils discussed the reliability of weather forecasts.

Yvonne thought that the forecasts issued by the Dominion Meteorological Division were usually right. "The forecaster doesn't just guess," she said. "He bases his judgment on a large number of weather facts that are gathered by means of accurate scientific instruments at weather stations all over Canada and the United States and over the oceans as well. His forecasts are not guesswork."

Michael Voss claimed that the long-range forecasts to be found in almanacs were usually reliable, but Bill Curtis disagreed with him. Bill said that the almanac weather predictions were the same for all of Canada and therefore were not dependable. Usually, the weather in Eastern Canada is quite different from that in Western Canada.

"Sometimes the 'weather man' makes some bad mistakes; however, most of the time he is right," commented Donna Kubo.

"Most of the time the weather forecaster is a poor guesser. I could do as well myself. I agree with Michael; the almanac forecasts are just as good as any," added Johnny Grotski.

(*a*) Which of the pupils do you think showed a good scientific attitude in their discussion? Why?

(*b*) What pupils appeared to lack a good scientific attitude? Why?

(*c*) Suggest ways in which the pupils might settle their argument in a scientific manner.

Hoard's Dairyman

In our good drove, so sleek and fair,
No bones of leanness rattle;
No tottering hide-bound ghosts are there,
Or Pharaoh's evil cattle.
Each stately beeve bespeaks the hand
That fed him unrepining;
The fatness of a goodly land
In each dun hide is shining.

—J. G. Whittier

CHAPTER 8

CHAPTER 8

DOMESTIC ANIMALS

Domestic animals make many important contributions to Canadian agriculture, in the form of food, materials for clothing, and other products. Livestock from many parts of Canada have won hundreds of awards at local fairs, at the Royal Winter Fair, Toronto, and at the International Livestock Exposition in Chicago. Does this not speak well for the quality of Canadian farm animals? What are the characteristics of the best animals in each breed? Many farm animals bear little resemblance to their ancestors of long ago. For example, the horse originally was not much larger than a small dog, and had five toes on each foot. How have the fine types of animals that we see today been developed from such unpromising beginnings? Are farm animals still being improved?

EVERYONE LIKES to attend a fair, to see the prize-winning livestock, vegetables, flowers, fruit, and grain, to hear the bands playing, to ride the merry-go-round and ferris-wheel, and to enjoy popcorn and candy-coated apples. When the exciting day came for Walter Emery's and Charles Parker's promised visit to their local fair, one of the things they most wanted to see was the livestock exhibit. Soon after their arrival at the fair, the boys met their fathers at the barns where the livestock were being prepared for judging. Each animal was being combed and brushed to make it look its finest. In the show ring, groups of judges moved about studying and comparing the animals and making brief notes. Finally, for each breed of livestock, the winners were announced, and colored ribbons were awarded. How pleased and proud the animals' owners were!

Later, on the way home, the boys asked their fathers many questions about the prize-winning livestock they had seen. They wondered why farmers were interested in finding out which were the best animals. They

This boy is proud of the Hereford calf that he has raised and trained to be shown at the fair. (Larry Shaw photo)

also asked how the judges could determine which animals were superior. As you read through this chapter, you will find the information given by Mr. Parker and Mr. Emery in reply to the boys' questions.

USING AND IMPROVING DOMESTIC ANIMALS

Mr. Parker pointed out that farm animals make many important contributions to Canadian agriculture, in the form of milk, beef, pork, mutton, wool, and eggs. The value of the production from Canadian farm animals amounts to many millions of dollars each year. The amount is greater today than ever before, because man has continually improved his domestic animals and has developed livestock suited to particular purposes. The farmer continues the improvement of his livestock by selecting the superior animals and using their offspring for his future herds. Livestock exhibitions, such as those held at local fairs, help in the selection of the superior animals in each breed.

"Everyone benefits from man's work in improving domestic animals," Mr. Emery added. "As more and better materials for food and clothing are produced by farm animals, there is more for everyone, and society as a whole benefits. The additional products are not all used in our own country; many of them are shipped to

A group of Junior Farmers prepare their Holstein calves for judging. What have these teen-agers learned from raising their own calves? (National Museum of Canada photo)

Britain and other countries, where they help to feed a hungry world. In exchange, we import other useful products."

How are livestock useful?

Every day we use a variety of materials produced by domestic animals. *Dairy cattle* provide us with milk and such dairy products as butter, cheese, cottage cheese, and cream. *Beef cattle* supply us with beef. *Sheep* provide mutton for food, and wool for clothing. From *hogs* we obtain pork, ham, and bacon. The hides of *cattle* and *horses*, when processed, become leather for shoes, gloves, and other articles.

Many classes of *poultry* also make contributions to our diet. *Chickens* supply us with eggs and meat. *Ducks*, *geese*, and *turkeys* are also important sources of meat.

Farmers have found that livestock, where they can be raised profitably, help in many other ways to develop a permanent system of agriculture. Farm animals help to maintain the fertility of the soil. Every bushel of grain raised on a farm, and every basket of fruit and vegetables picked from the orchard and garden, removes valuable substances from the soil. Unless these plant foods are returned, the soil, in time, becomes useless for growing crops. One way in which plant food materials may be restored to the soil is by adding to it manure, which is available only where livestock are raised. Manure not only returns plant food materials to the soil, but also improves the soil by loosening the soil particles, thereby letting air and water in to the roots. Farmers who do not raise livestock, and gardeners who grow top-quality flowers and vegetables, often find that they need to buy barnyard manure to retain or restore the fertility of the soil. Soil fibre and fertility may also be maintained by growing grasses and legumes periodically. These crops should therefore be included in every system of crop rotation, but they are most profitable where they can be used as food for livestock.

Livestock often enable farmers to turn to profit many products that otherwise might be wasted. Skim milk may be fed to pigs and calves. Much low-grade grain may be profitably fed to farm animals. During warm weather, small flocks of poultry pick up much of their food around the farm.

A monument to a Holstein cow, erected near Woodstock, Ontario. During her lifetime, she produced over 100 tons of milk, containing 9062 pounds of butter-fat, a world's record at the time. Why would her calves be valuable additions to a Holstein herd? (Ontario Department of Travel and Publicity photo)

A few cows, pigs, and hens will provide the farmer and his family with a large part of their food supply.

On many farms, sheep, in addition to producing wool and mutton, help to control weeds.

Livestock ensure a constant revenue for the farmer because such products as milk, eggs, dressed poultry, meat, and live animals can be sold at times of the year when there is little revenue from other farm produce.

Good livestock add to the enjoyment of farming. There is much pleasure to be derived from raising fine beef cattle, or from owning high-producing cows.

Improving livestock by domestication

All types of domestic animals were once wild. Man very early learned that hoofed animals were less dangerous to hunt than flesh-eating ones, and he found their flesh more delicious to his taste. Later, he learned that some of these animals could be easily tamed. He used the horse to carry heavy loads. Cattle, goats, and sheep were herded to supply milk and meat, and material for clothing. Records show that these food-producing animals have been domesticated in various parts of the world for thousands of years.

In their wild state, most animals differed greatly from their modern descendants, and they produced much less food and clothing material. For examples, cows produced only enough milk to raise their calves, and hens laid about 15 eggs a year, only enough to raise a brood of young. By contrast, many cows today produce more than *10 tons* of milk yearly, and many hens lay more than *300* eggs a year.

After removing a White Leghorn hen from a trap nest, a poultryman reads the number on her leg band. What use will be made of this information? (National Film Board photo)

After animals were domesticated, they began to show marked improvements. Being protected from their natural enemies gave them a chance to consume more food and to grow larger, heavier bodies with a greater proportion of meat. With better food, particularly in cold seasons, and with shelter from the weather, the animals developed more rapidly. Regular milking of cattle brought about greater and more prolonged periods of milk production. The shearing of sheep resulted in a better quality of wool. The daily removal of the eggs from their nests discouraged hens from setting; this, in turn, caused them to continue to lay more eggs.

Livestock to serve special purposes

As animals gradually became more productive, some of them were selected for special purposes. Thus we have *dairy cattle* and *beef cattle*, different types developed for different purposes, the one to produce large quantities of milk, the other to provide large amounts of high-quality meat. Similarly, horses were developed as two types, one for strength, the other for speed. Even chickens belong to special types; some lay large numbers of eggs, while others grow heavy, meaty bodies.

Good care, protection, proper foods, and the selection of special types have brought about gradual improvement

in livestock for many centuries. However, the greatest improvement in farm animals has been accomplished in the last two centuries. As you will see as you read this chapter and study the breeds of farm animals shown, the farmers of Great Britain and Northern Europe have made remarkable contributions to the development of present-day types and breeds of livestock.

Throughout the centuries, man's aim in improving livestock has been to develop animals to suit his own needs and those of the society in which he lived. There are now a number of *classes* of livestock, such as horses, cattle, hogs, and sheep. Within each class there are a number of *types*, such as dairy cattle, beef cattle, draft horses, bacon hogs, mutton sheep, etc. All the animals in each type possess certain *general characteristics*, which make them similar to each other, and particularly valuable for a certain use. For example, *Holstein* cows and *Ayrshire* cows are different in size and color, but they are similar in the shape of their bodies and in their ability to produce large amounts of milk. Both of these kinds of cows are of the *dairy type*.

Within each type are a number of *breeds*. The Holstein is a breed of dairy cattle. All members of each breed have descended from the same ancestors; all Holsteins are descendants of a small group that were developed in Holland. All animals of one breed have *distinctive characteristics*, such as coloring. All Holsteins are black-and-white. You would not expect to see Holsteins of any other color.

What are purebreds?

With respect to their ancestry, we classify farm animals as *purebreds*, *grades*, and *scrubs*. A purebred is an animal whose ancestors have been of the same breed for many generations. In Canada, the record of a purebred animal's ancestors, or its *pedigree* as it is called, is registered with the Canadian National Livestock Records Association, Ottawa.

A grade animal is one with one purebred parent. In the case of a scrub animal, neither parent is a purebred.

It has been found that purebreds are usually more profitable to raise than either grade or scrub animals. Inferior animals eat as much, and require nearly as much care as better ones, but the financial returns from them are smaller. In recent years, the numbers of grades and scrubs have been decreasing.

Improvement by selection

The best way of bringing about gradual improvements in livestock is by selecting the best animals in each herd and raising their offspring. In every herd of cattle there are some cows that produce greater amounts of milk, or milk of higher quality, than the rest. In every pen of hogs, some grow more rapidly than others. In every flock of hens, a few lay more eggs than the remainder. It has been

known for many years that the offspring of these higher-producing animals usually *inherit* these desirable qualities. Therefore, if a farmer plans to improve his stock, it is essential that he find his higher-producing animals and raise their offspring.

How do farmers practise selection?

To find the best animals in his herds and flocks, the farmer must *keep accurate records* of the production of his animals. The dairy farmer keeps a record of the *weight* and *butter-fat test* of the milk produced by each cow. This *record of production* enables the farmer to select the cows whose calves he will raise.

The poultry farmer who wishes to improve his flocks has his own method of checking the production of each hen. The chickens lay their eggs in *trap-nests*. After laying, the hen cannot get out of the nest until the farmer releases it. In this way he can keep a record of the number of eggs laid by each hen. He sets for hatching only those eggs laid by the best layers. Many farmers, instead of keeping records of their flocks, prefer to buy chicks from reliable hatcheries that keep accurate records and hatch eggs laid by hens of known high production.

Farmers also select the best animals in other classes of livestock. In the case of sheep, those with the most wool, those with long, fine wool, or those with the best mutton-type bodies, are chosen. Pigs that grow

The crossing of a top-quality bull with inferior cows brings about improvements in the quality and production of their offspring. As shown, these improvements may often be seen in the first generation. Point out several ways in which the offspring is superior to the parent cow.

most quickly, and produce carcasses of the right type, with suitable proportions of fat and lean meat, are preferred. Horses are selected for size, strength, endurance, and temperament. Often it is possible to choose the finest animals merely by careful observation of each animal's body structure, to see how closely it compares with the *distinctive characteristics* of the breed.

An experiment with hens shows the importance of body shape in egg production. From a large flock of hens, an expert poultryman selected 100 with excellent body shapes, and 100 with very poor shapes for egg production. The two flocks were kept in similar pens and given identical food and care. During the following six months, the 100 hens with good body formation laid an average of 83 eggs a day; the group with poorer body shapes laid an average of only 39 eggs a day.

As you know, at local, provincial, and national fairs, the finest animals of every breed are exhibited and judged. Competent judges study each animal to see how well it displays the distinctive characteristics of the breed; thus they choose the outstanding specimens of each breed. It is indeed a great honor for a farmer to have one of his animals win a top award. The winning of ribbons at local fairs, and at larger ones such as the annual Royal Winter Fair in Toronto and the International Livestock Exposition in Chicago, serves to advertise the best livestock, so that other farmers can find out where to buy animals to improve their own herds.

Improving by scientific breeding

To further improve his herd of cattle, the dairyman crosses his select cows with bulls that have had high-producing ancestors. The offspring often are superior to either parent because they inherit high-producing qualities from *both* parents.

The crossing of hens of high egg production with roosters from high egg-producing ancestry brings about an improvement in the egg production of their offspring.

Scientific breeding has also resulted in marked improvements in horses, sheep, and hogs.

You probably have learned that plant scientists frequently improve plants by *cross-breeding,* to increase yield, to resist drought and plant diseases, and to improve the quality of the plant's food products. Cross-breeding is also sometimes employed to improve animals for particular purposes. For example, the cross-breeding of chickens of high egg production with chickens from breeds that produce large amounts of meat has given us chickens with the useful qualities of both parent breeds.

An experiment in cross-breeding solved a problem of the ranchers of the southern United States. Most breeds of beef cattle do not thrive in the heat of this area. However, a rancher imported from India some cattle that were accustomed to such a climate. Unfortunately, these cattle

produced very little good beef. By cross-breeding Herefords and the imported Indian cattle, a new breed was developed that thrives in the heat and also produces large amounts of fine beef.

In recent years, many experiments in cross-breeding hogs have been used to improve bacon production. The cross-breeds, or *hybrids,* developed by crossing two types of purebreds usually are more vigorous and often grow more rapidly than purebreds.

While cross-breeding has developed animals for particular purposes, it has been found that purebred animals are usually more productive than animals of mixed ancestry.

Improved feeding and care

In recent years, *improved diets* have brought about marked increases in the rates of growth of various animals, and in their production of milk, beef, mutton, wool, pork, and eggs. Improved methods of curing and storing hay have helped to retain the valuable food nutrients it contains. The diets of animals have been improved by the addition of proteins, minerals, and vitamins.

Better care also results in better production from most farm animals. Such conditions as fresh, clean water, dry bedding, clean quarters, sufficient space for exercise, ventilation, shelter in winter, shade in summer, plenty of light, and spraying for flies have helped to increase the amount and quality of products from livestock.

SOMETHING TO DO

1. Visit a farm in or near your community where purebred livestock are raised. Ask the farmer to show you how he keeps records of production, or in other ways practises selection of his animals.
2. If possible, visit a poultry farm to see trap-nesting in operation.
3. Obtain the registration certificate of a purebred animal, so that you may study its pedigree, or the record of its ancestry.
4. Visit a local fair to observe the judging of livestock. Find out the points on which each breed is judged.
5. Start now to collect pictures of prize-winning animals in each breed of livestock. Later, as you study each breed, organize your pictures in a livestock booklet.

How are other animals improved?

The processes of careful selection and scientific breeding are applied to many other kinds of animals. In recent years, experiments in cross-breeding *mink* have developed animals of a wide variety of colors. Some of these surpass the natural color in beauty and quality, and bring the fur farmer higher prices. The success of these experiments has been one reason for mink becoming the most popular fur bearer raised in captivity. *Foxes,* too, have been improved so that they produce finer pelts than their wild ancestors.

Did you ever wonder how it came to be that there are so many kinds of *dogs?* In different parts of the world, man domesticated various

Certain fur-bearing animals can be profitably raised on fur farms. The valuable dark mink (top) and the black silver fox were developed through experimentation in selecting and cross-breeding animals with variations in color. Canadian furs are known to be of high quality, and are much in demand in other lands. Buyers come from many countries to large fur sales in Montreal, Toronto, Winnipeg, Regina, Edmonton, and Vancouver. (Top, R. W. Menzel photo; bottom, Department of Northern Affairs and National Resources photo)

kinds of wild dogs. Since that time he has developed and improved dogs of many kinds for various purposes — to hunt deer, rabbits, birds, and other game; to act as watch-dogs; to herd sheep and cattle; to pull his dog-sleds; to be house pets; etc. For each purpose, a different kind of dog was developed by the processes of selection and scientific breeding.

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. What are some of the contributions that Canadian farm animals make to the world's food supply?
2. Why are livestock important in retaining the fertility of the soil, and in establishing agriculture on a permanent basis?
3. In what other ways are livestock useful on Canadian farms?
4. In your own words, explain what is meant by each of the following terms as applied to farm animals: type, breed, purebred, grade, scrub, pedigree.

Four breeds of dogs commonly raised in Canada: Top left, American Cocker Spaniel; top right, Collie; bottom left, Irish Setter; bottom right, German Shepherd. These prize-winners show the characteristics of each breed. For what purposes was each breed developed? (Photos from *Dogs in Canada*)

5. (*a*) Why do farmers practise selection of their livestock?
   (*b*) Describe two methods of selecting top-quality animals.
   (*c*) How do fairs help in the work of selection?

6. Briefly describe how one type of animal could be improved for a particular purpose – for example, horses for pulling heavy loads; cattle for beef production; hogs for bacon; hens for the laying of large numbers of eggs; dogs for hunting.

DAIRY CATTLE

Many centuries have passed since man first domesticated the wild cattle that once roamed the grassy hills of Great Britain, France, Holland, and several islands in the English Channel. Through the years, the cattle of high

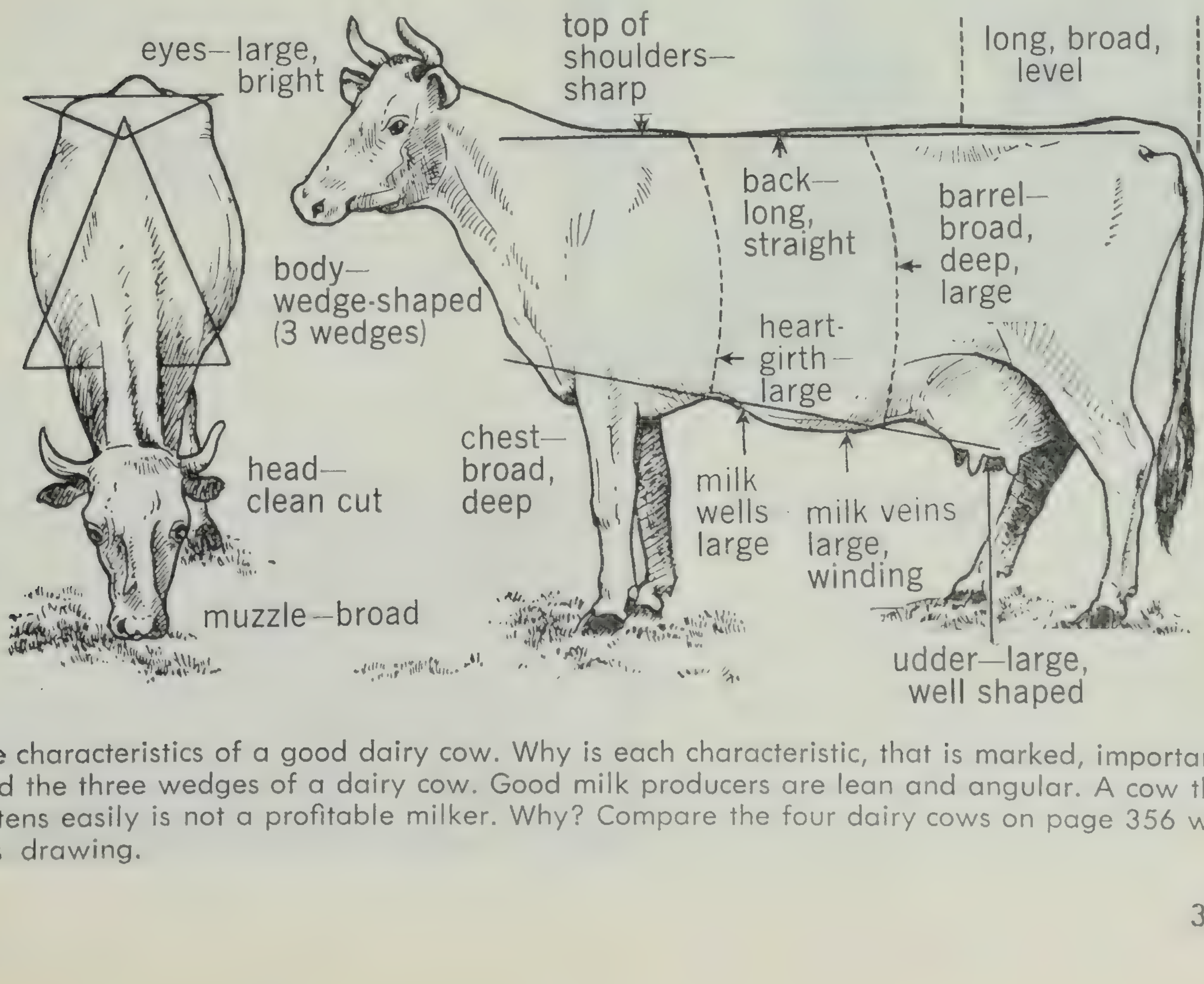
milk production have been selected and improved to the point that dairy cattle today are truly specialized milk producers.

Dairying is the chief branch of the livestock industry in many parts of Canada. Near our larger cities, dairying is the chief type of farming, because of the need of supplying the city populations with large amounts of fresh milk, cream, butter, and cheese. In addition to the quantities of dairy products used at home, our cattle supply dairy products that are exported to the United States, Great Britain, and other lands.

We need better cows

No other animal is more efficient than the dairy cow in changing grain and grass into palatable, nutritious human food of high value. The dairy cattle of Canada, for the most part, are good, but there is still much need for improvement. It is possible for the best cows to produce, in one year, about 10 tons of milk, and about 700 pounds of butter-fat. The average production in Canada is less than half of these figures.

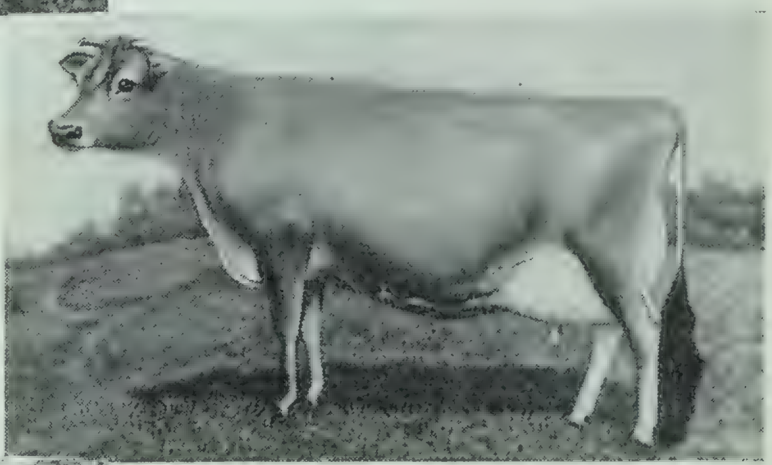
Dairymen should keep a careful record of the milk production and butter-fat test of each cow, so that they can determine which of their animals are the most profitable, and which, if any, are "boarders," costing more for their feed than the value of the milk they produce. By keeping such records, and using the information to improve his herd, the farmer



The characteristics of a good dairy cow. Why is each characteristic, that is marked, important? Find the three wedges of a dairy cow. Good milk producers are lean and angular. A cow that fattens easily is not a profitable milker. Why? Compare the four dairy cows on page 356 with this drawing.

This photograph and the three below illustrate our four common breeds of dairy cows. The Holstein is the most popular breed of dairy cow in Canada. Holsteins originated in Holland. They are black and white, and are the largest of the dairy cows. While their milk is not as rich as that of some other breeds, they produce the largest quantity of milk of any cow. (Ontario Agricultural College photo)

The Jersey, the smallest of the dairy breeds, originated on the Isle of Jersey in the English Channel. Jerseys are usually fawn in color, varying in shade from light to almost black. Although not heavy milkers, they produce milk high in butter-fat content. (Ontario Agricultural College photo)



The Ayrshire, a hardy dairy breed, was developed in the Ayr Valley, in the southwest of Scotland. Ayrshires are red and white, with long, upright horns. They rank second to Holsteins in size and milk production. (Ontario Agricultural College photo)

The Guernsey is the least common of the four dairy breeds in Canada. The breed was developed on the Isle of Guernsey. These cows are larger than Jerseys, and have the same fawn color, broken by white patches. They give more milk than Jerseys, but the milk has a lower butter-fat content. (Ontario Agricultural College photo)

can make more profit, and at the same time can improve the quality of future livestock, to the benefit of mankind.

Characteristics of dairy cattle

The four breeds of dairy cattle commonly raised in Canada – Holstein, Ayrshire, Guernsey, and Jersey – are all similar in a number of ways. Each breed can be recognized by its color, size, and general appearance. Learn to recognize these four breeds; learn how to identify each, and look for ways in which all are similar.

A dairy cow must be capable of eating and digesting large amounts of grass and grain; she must therefore have a deep body and ribs that are widely spread. She should appear lean and angular, because her food should be used to produce milk instead of meat. The hide should be glossy, and the hair fine. The diagram on page 355 shows you the characteristics of a good dairy cow.

It is easy to see the differences between the dairy cow's wedge-shaped body and the blocky appearance of beef cattle (see page 366).

TEST YOUR KNOWLEDGE AND UNDERSTANDING

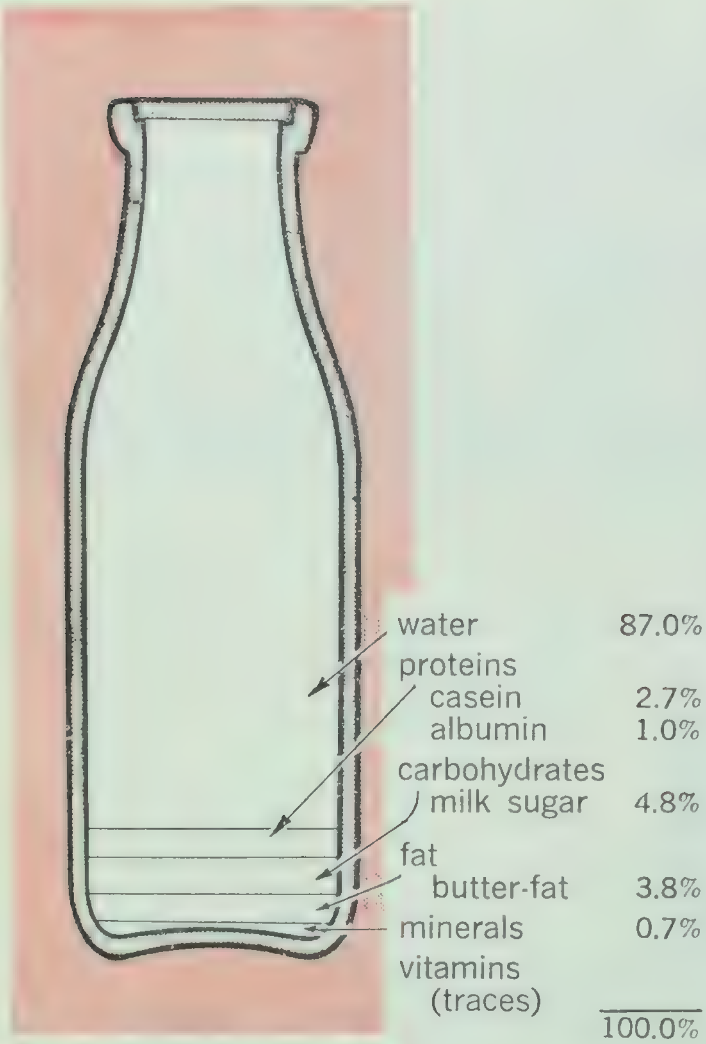
1. Why should a farmer keep careful records of the milk production and butter-fat test of each cow in his dairy herd?
2. Describe the characteristics of a fine dairy cow.
3. What four dairy breeds are commonly raised in Canada? How can we recognize each breed?

MILK — OUR MOST NEARLY PERFECT FOOD

Milk, which comes to us from dairy cattle, is often called "the most nearly perfect food." It is easy to digest, and contains nearly all the nutrients required for healthy, active life and growth. Nature has prescribed milk as the only food for young mammals. The young of humans, cattle, horses, cats, dogs, and other mammals live solely on milk during the early days of their lives. We never outgrow our need for milk and milk products. Babies live almost entirely on milk; as we grow older, we should continue to drink several glasses of milk each day. Besides drinking milk, we should use it on cereal, and in puddings and other foods. By eating plenty of butter and cheese we supply our bodies with some of the important nutrients in milk.

Examining the food materials in milk

You can discover for yourself the variety of food materials found in milk by examining its various parts.



The component parts of whole milk. Why is milk a valuable food? In Canada, whole milk delivered from door to door must contain at least 3.25 per cent butter-fat.

SOMETHING TO DO

1. Obtain a pint of fresh milk. (For this study do not use *homogenized* milk, which has had the butter-fat globules broken up so finely that they do not rise to the top.) Let the milk stand for a day. Observe the layer of *cream* that has risen to the top. What fraction of the milk is cream? Rub a few drops of cream on a piece of paper.

The grease spot on the paper shows you that *fat* is present in the cream, which in turn is a part of whole milk. Cream contains *butter-fat,* which, as the name suggests, forms the major part of butter. If you are able to look at a drop of cream through a microscope, you will see tiny round globules of butter-fat in it.

Cream can be removed from milk by pouring or skimming it off after it rises to the top, or by separating the cream and the skim milk with the use of a *cream separator.*

Butter-fat is an important part of milk because it contains *fat.* Fats, along with *carbohydrates,* are the energy foods that keep our bodies warm and supply energy for work and play. For this reason, the percentage of butter-fat in the whole milk that we use is carefully tested. Dairies are required to have, in the whole milk that they sell, a minimum of 3.25 per cent butter-fat. By supervising the butter-fat content of milk offered for sale, the government helps to safeguard our health and to ensure that true value is received for our money.

The butter-fat content of milk also serves as a means of deciding the price that dairies will pay for milk. At the dairy, the milk from each farm is carefully tested to find out the percentage of butter-fat in it. The higher the percentage of butter-fat, the higher the price paid for the milk. Many farmers test the butter-fat content of the milk produced by each cow. A record of this information is useful in selecting the animals in the herd that are the best producers.

You have learned that Jersey cows produce less milk than Holsteins, but that their milk contains a higher percentage of butter-fat. Why do some

farmers find that Jerseys provide as much profit as Holsteins, even though they give less milk?

2. Remove the cream from the milk that you are examining. Allow the *skim milk* to stand in a warm room until it becomes sour. You can cause it to sour quickly by adding to it a few drops of vinegar and letting it stand for an hour. Describe the appearance of the sour milk.

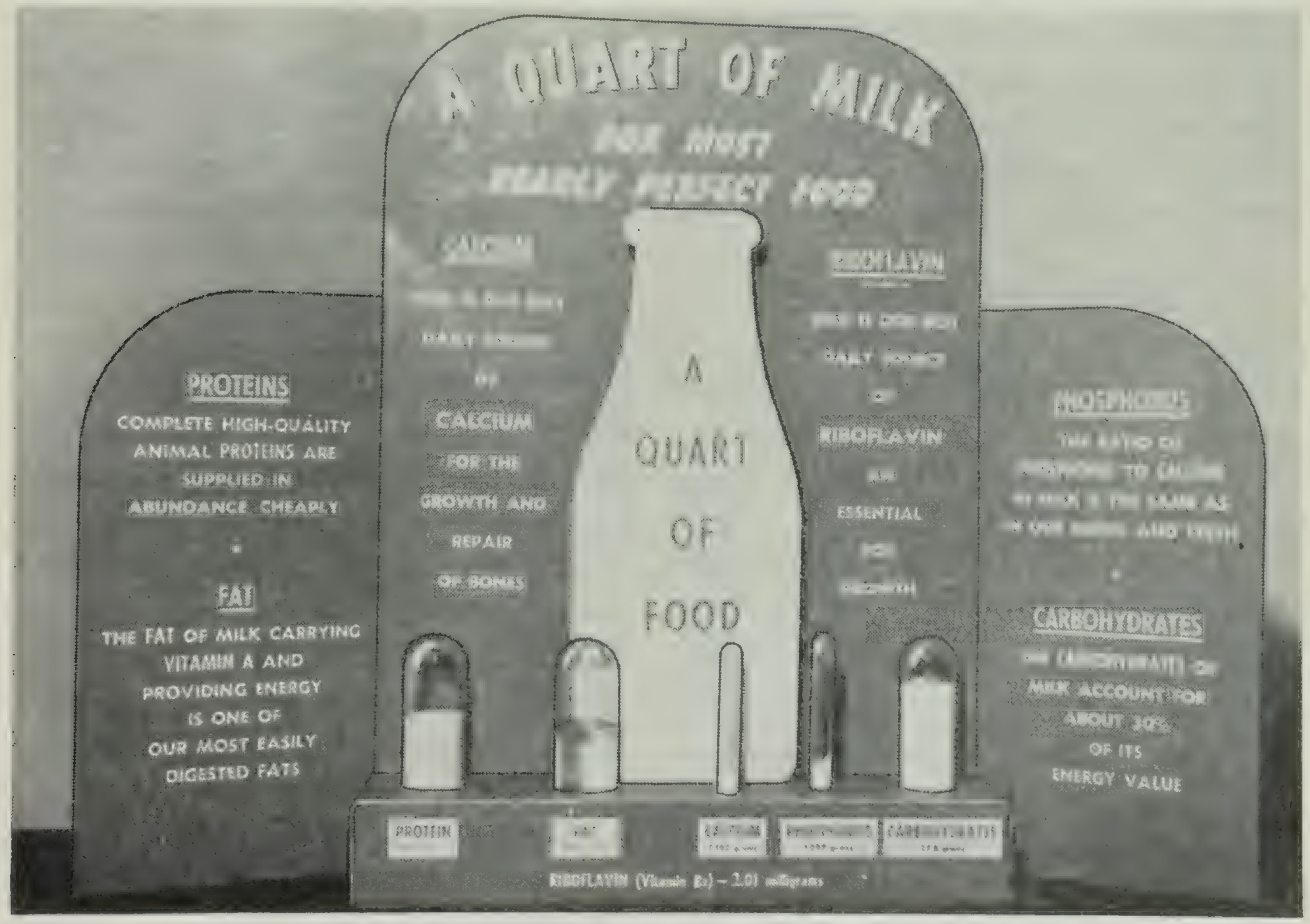
When milk becomes sour, it separates into the two parts that you have observed. The thick curds, called *casein,* are used in making cheese. The thin, partly clear liquid is called *whey.*

Casein is an easily-digested *protein,* the type of food your body needs for growth and repair. Milk and cheese compare favorably with eggs and beef in the amounts of protein they contain.

Whey is composed chiefly of water, but it also contains several important food elements.

3. Heat a beaker half-full of whey, without stirring it. What appears on the surface of the whey? Instead of whey, you can use whole milk, heating it almost to the boiling point.

You have discovered in milk another protein, known as *albumin.* If you



What important food elements in milk are shown in this chart? Why is each important? (Associated Milk Foundations photo)

have boiled milk to make hot cocoa, you have probably already seen the layer of albumin that forms on the top of the milk.

4. Skim off the albumin. Boil the remaining liquid until all the water evaporates, but do not let it burn. After it has cooled, taste the dry substance in the dish. Has it a sweet taste?

The greater part of the sweet, white, dry substance that remains is *milk sugar,* a carbohydrate in milk. Because of the butter-fat and milk sugar that it contains, milk is one of our best sources of food for heat and energy. A quart of milk contains more energy food than a half-pound of potatoes or a piece of apple pie.

5. Place the milk sugar on a piece of metal or mica and heat it in a flame until the milk sugar burns. What remains after burning?

The small amount of *ash* that remains after burning, contains a number of *minerals.* Milk is a major source of two minerals essential for general health and for the development of strong teeth and bones. Most of our *calcium* and *phosphorus* are obtained from milk; it contains far greater amounts of these minerals than does any other common food. Milk also supplies a small amount of *iron,* which is also provided by meat, fish, and fresh vegetables.

The *water* in milk provides us with a large share of our daily supply of this vital liquid.

Milk is also an important source of three *vitamins,* Vitamin A, Vitamin B (thiamine), and Vitamin B_2 (riboflavin), which are necessary for general good health. In addition, it contains small amounts of Vitamins C and E. Butter is also a fair source of Vitamin D; however, in winter it contains insufficient Vitamin D for young people. At this season, we should add cod liver oil to our diet. The amounts of vitamins in milk are great enough to influence our health, but are too small for us to separate them readily for observation.

A careful study of the drawing on page 358 will help you to review the parts of milk, and will show you the percentages of each of the component parts in whole milk.

When you consider the amounts of important foods in milk, and compare them with the amounts in other items in our diet, is it any wonder that we refer to milk as "the most nearly perfect food"?

Milk must be kept clean

Milk that is handled carelessly soon becomes unfit for food. It furnishes an ideal growing place for many kinds of *disease bacteria,* such as those that cause *typhoid fever, tuberculosis,* and *diphtheria.* It is, of course, very dangerous to use milk in which these bacteria are present. Many serious outbreaks of disease have been traced to the milk supply of the district in which they occurred. Once bacteria get into milk, they increase in numbers very rapidly.

Milking time in a large, modern dairy barn. Notice the milking machines and scales for weighing the milk from each cow. What evidences of cleanliness do you see? (*Ontario Milk Producer* photo)

Harmful bacteria may enter the milk in many ways: they may be in the milk as it comes from the cow; they may fall from the body of the cow, from dust in the barn, or from the hands and clothing of the milker; they may lurk in unclean pails and bottles.

Because sick cows may transfer bacteria to the milk, wise farmers make every effort to keep their herds in healthy condition, and arrange from time to time to have their cows tested for diseases, especially tuberculosis. In many places, the law requires that all herds be tested periodically for tuberculosis. Farmers should also keep their barns clean to reduce the risk of bacteria in the air and in the litter on the floor. Before milking, they should clean the udder and flanks of the cow so that dirt cannot fall into the milk. They should then wash their hands carefully. Milk should be placed only in utensils that have been sterilized thoroughly by scalding. After milking, the milk should be removed at once from the stable, strained through a fine cloth, placed in clean, odorless, covered cans, and kept at a low temperature (less than 50° F.). If possible, the milk should be sent to the dairy every day. Some modern dairy farms use special coolers that keep the milk at a temperature just above its freezing point. At this temperature, bacteria cannot grow and multiply, and the milk may be kept on hand safely for several days.

SOMETHING TO DO

1. Test the effect of cool and warm temperatures on the rate at which milk becomes sour. Pour equal quantities of fresh milk into two similar bottles. Keep one in a refrigerator or in another cool place, and leave the other in a warm room. Observe and smell both samples daily. How long did each sample take to become sour? What do you conclude?

2. Why should milk be kept covered? Pour fresh milk from one bottle into two test tubes until each is half full. Plug the mouth of one test tube with cotton batting to prevent dust from entering. Leave the other one open. Place the two samples side by side in your classroom. Observe

In modern dairies, samples of the milk from each farm are carefully analyzed. This scientist is studying the presence of bacteria in samples of milk. Notice the sanitary conditions in this laboratory. (*Ontario Milk Producer* photo)

both each day. Which one became sour first? Why?

NOTE. — In these experiments, it would be a good idea to use several pairs of samples, or to repeat the experiment several times before you reach a final conclusion.

The souring of milk is caused by the action of harmless bacteria in the milk. Sometimes these bacteria are useful, as when they sour milk for making cheese. However, we do not usually want milk to become sour. We should therefore keep the milk covered to keep out the bacteria that are in the air. Milk should also be kept cool, because bacteria cannot grow readily in cold places.

Another good reason for keeping milk covered and cold is to prevent the entry and growth of disease bacteria and types of bacteria that cause milk to *decay* instead of turning sour. Have you ever seen and smelled milk that had a brownish color and a foul odor? It probably was spoiled by *decay bacteria.* These bacteria are often present in room dust.

Making milk safe by pasteurization

Because disease germs can easily enter milk, creameries and dairies that receive milk from many farms *pasteurize* it before selling it to their customers. This may be done in either of two ways: (1) The milk is heated to a temperature of 145° F. and held there for 30 minutes, and is then quickly cooled to 50° F. (2) The milk is heated to a temperature of 161° F. for 16 seconds, and is then quickly cooled to 50° F.

In pasteurizing, the heat kills all disease germs without changing the flavor and food value of the milk. Some bacteria, such as those that cause milk to turn sour, are not destroyed by pasteurization. However, their presence in the milk does not endanger our health. In most localities, the law requires milk to be pasteurized if it is to be sold. Is this the case in your community?

At your home or summer cottage, if it is necessary to use milk that has not already been pasteurized, you can pasteurize it in the top of a double-boiler. Heat water in the lower part to bring the milk to the required temperature. Of course, you can also destroy the bacteria by boiling the milk, but this affects the taste.

SOMETHING TO DO

1. Does pasteurized milk keep better than unpasteurized milk? Pour equal

quantities of pasteurized and unpasteurized milk into two test tubes. Label them. Plug each opening with a cork or some cotton batting, and let the tubes stand in your classroom for several days. Observe and smell the milk in each tube every day. In which tube did the milk sour first? In which tube did the milk first show signs of decay? What do you conclude is the effect of pasteurization on the keeping quality of milk?

2. The process of pasteurization is named for Louis Pasteur, who first proved that diseases are caused by bacteria. Read the story of Pasteur, and learn how this great French scientist used the scientific method in making many discoveries that helped to form the foundation of modern medical science.

Butter-making

We know that butter is made from cream (usually sweet cream), which is separated from skim milk by a cream separator. To cause the globules of butter-fat to collect together, the cream is shaken vigorously in a *churn* until butter begins to form. Salt and often coloring are added to the butter. You can buy *creamery butter*, which is made at creameries, and *dairy butter* which is usually made on farms. Although much dairy butter is of excellent quality, creamery butter is usually preferable because it is made from pasteurized cream, is always made under clean conditions, is carefully graded, and is made according to exact standards, so that the color and flavor and the amount of salt are more uniform than in dairy butter.

SOMETHING TO DO

1. Make some butter at school. Pour a half-pint of cream into a pint sealer, and screw the top on tightly. Shake the bottle vigorously, loosening the top from time to time to release the gas that forms. After fifteen minutes, you should see tiny lumps of butter forming. When a mass of butter has formed, pour off the *buttermilk* and wash the butter with clean, cold water. Now remove the butter to a plate and press out the excess water with a large spoon, preferably a wooden one. Add a pinch of salt, working it in with the spoon. Taste the butter.

NOTE. — You will find that cream forms butter most rapidly if its temperature is about 70°.

2. Visit a local dairy to observe:

(*a*) How milk is delivered to the dairy.

(*b*) How milk cans are sterilized to kill bacteria.

(*c*) How milk bottles are sterilized.

(*d*) How milk is pasteurized.

(*e*) How milk is homogenized.

(*f*) How a cream separator works.

(*g*) How a churn works.

(*h*) How cottage cheese is made.

(*i*) How butter-fat tests are made.

3. If possible, visit a cheese factory to see how cheese is made.

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. What are the six groups of essential food materials contained in milk? How is each important to us?

2. What would you do to samples of milk to locate each of the following: albumin, casein, whey, cream, milk sugar, minerals?

3. What care should farmers take to make sure that milk is kept clean? Why is such care necessary?

4. What care should be taken in the home to keep milk fresh and clean?

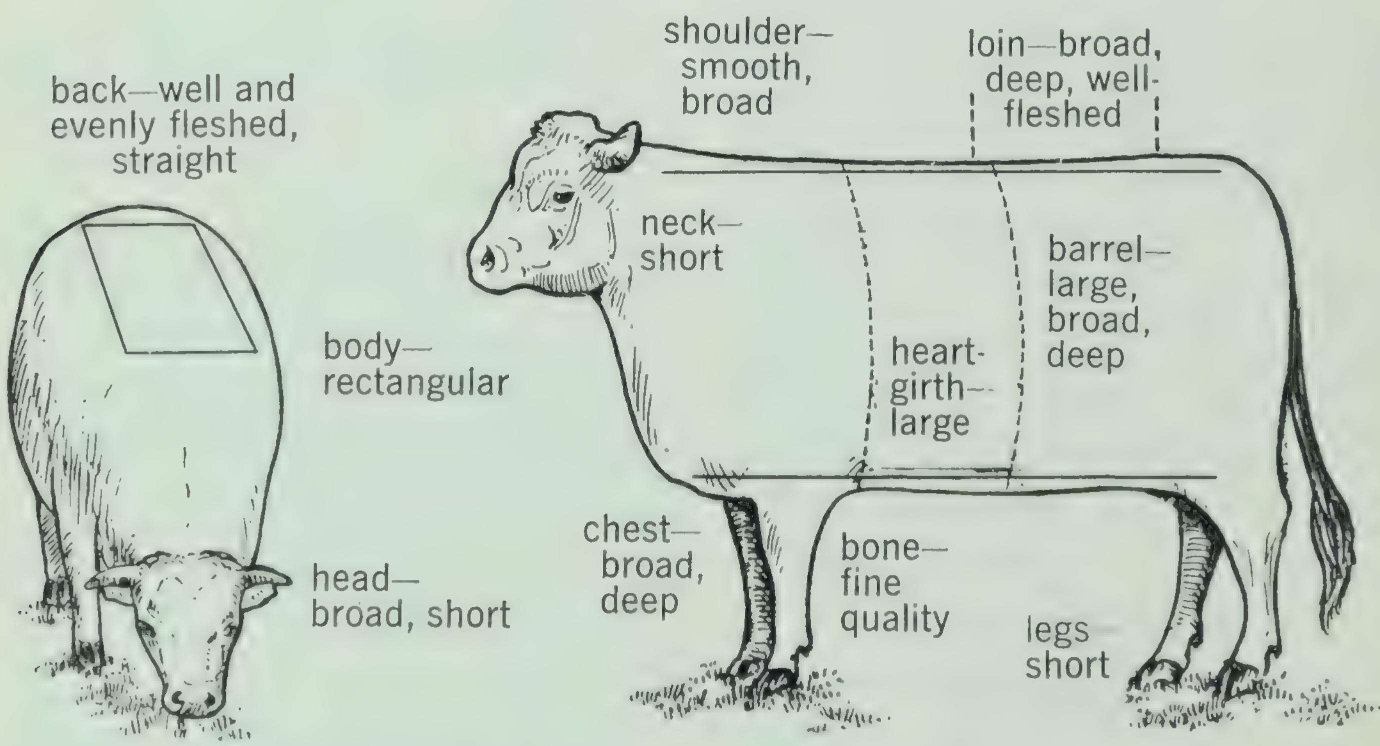
5. Describe the two methods of pasteurizing milk. Why should all milk that is offered for sale be pasteurized?

6. Write the story of a pound of butter from the time that it was a part of whole milk until the time when it was ready for sale.

THE PRODUCTION OF BEEF

On many farms in every province, beef cattle are a source of considerable revenue. Beef cattle do not require as much attention as dairy cattle, but they do require fairly good pasture and an adequate supply of fresh, clean water.

Some of the beef produced in Canada is marketed in Great Britain and other countries. All beef that is processed in large Canadian packing plants is inspected by government officials for the purpose of marking the grade, and to protect the public

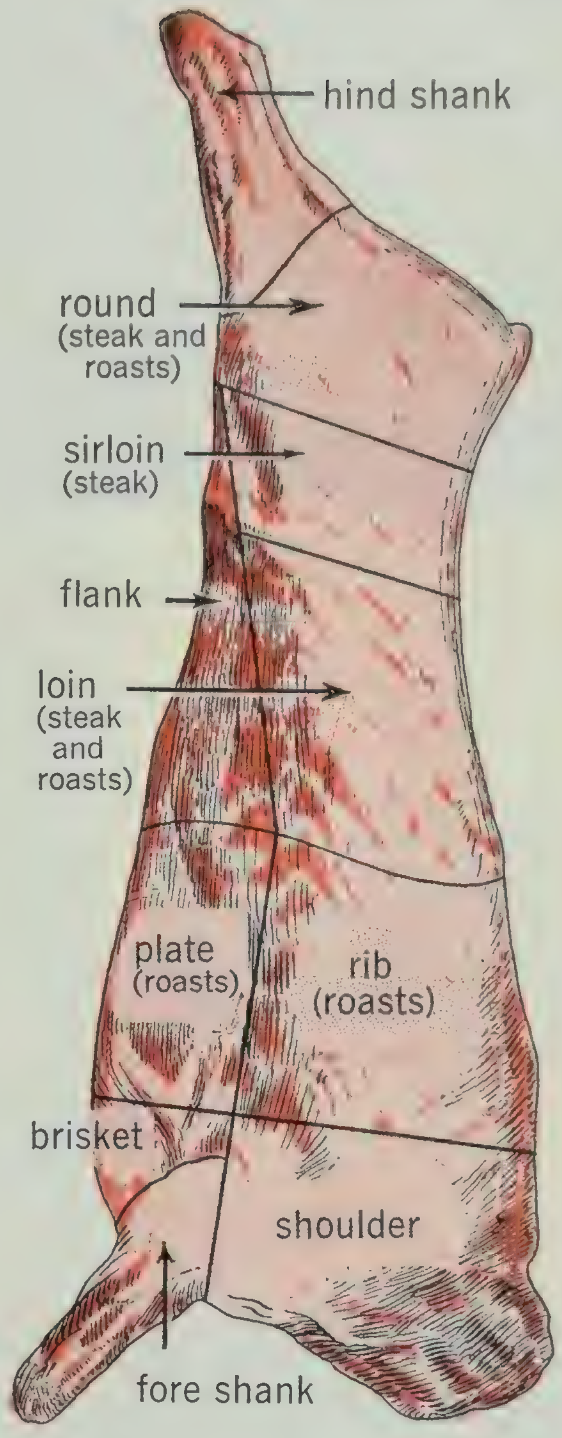


The characteristics of good beef cattle. They should be long, broad, deep, and low-set. The back should be straight and parallel to the underline, forming a box-like, rectangular body. What parts of the body should be especially well fleshed? Compare the three beef cattle on page 366 with this drawing.

from food poisoning from meat that is diseased.

The successful stockman must know how to recognize and raise the profitable type of beef cattle. By studying the illustration on page 364, you can see the characteristics of a good beef animal. The high-priced cuts of meat (see drawing) are found along the back, over the loins, and halfway down on the ribs and hind quarters. A good beef animal, therefore, must be well developed in these parts.

Beef cattle are good examples of domestic animals improved by selection and scientific breeding. The farmers of Great Britain, where all three of our common beef breeds originated, recognized long ago that some cattle were well suited for the production of a large amount of fine beef. By selecting the cattle with the best type of body for beef production, and by crossing them with other select beef cattle, the three breeds of beef cattle were developed.



A side of beef, showing the important cuts. Ask a butcher to tell you which cuts are the most expensive.

SOMETHING TO DO

1. Collect pictures of prize-winning beef cattle. Compare them with those shown in this chapter, and with the drawing on page 364 illustrating the characteristics of a fine beef animal.

2. Observe beef cattle at a fair or on a farm to see how they compare with the illustrations in this chapter.

3. Visit a butcher shop to see the various cuts of beef. Locate each cut by referring to the illustration above. On what parts of a beef carcass are the most expensive cuts located?

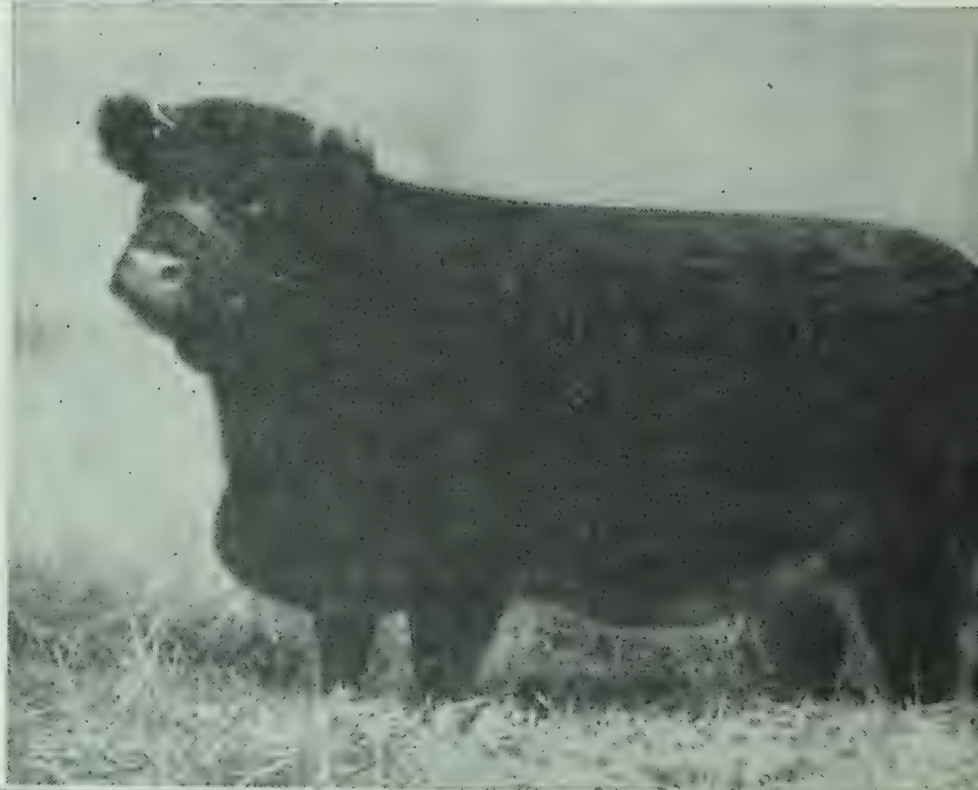
Dual-purpose cattle

Some breeds of cattle are adapted to the production of both milk and meat. They are known as *dual-purpose* cattle.

The *Milking* or *Dairy Shorthorns* are the most popular dual-purpose

Herefords, or "white faces," originated in Herefordshire, in the southwest of England. This is a grazing district, and Herefords are noted for their ability to produce beef from grass on the open range. Herefords are red, with white on the face, chest, underline, and tail. (Ontario Agricultural College photo)

Shorthorn cattle are red, white, red and white, or roan in color. Usually their horns are fairly short and curved forward. They were developed in the north-east part of England. (Jim Rose photo)



Aberdeen Angus cattle, which originated in Scotland, are black in color, and have no horns. They are slightly smaller than the other beef breeds. (Saskatchewan Government photo)

A Dairy Shorthorn cow (left) and a Red Polled cow. Why are these breeds referred to as dual-purpose? How are they similar to (1) dairy cattle, and (2) beef cattle? (Left, Ontario Agricultural College photo; right, Cook and Gormley photo)

breed of cattle raised in Canada. They were developed from early English Shorthorns. These cattle resemble the beef Shorthorns in color markings, but are less fleshy, and show some of the body characteristics of dairy cattle. Some of them are excellent milk producers.

The *Red Polled* cattle are natives of Eastern England. Their history dates back almost to the Roman period in Great Britain. As their name suggests, this breed is red and hornless. They are well covered with meat of high quality, and they produce a good quantity of fairly rich milk.

SOMETHING TO DO

If possible, examine dual-purpose cattle at a farm or a fair. Discuss with their owners the advantages and disadvantages of these cattle when compared with dairy and beef types.

TEST YOUR KNOWLEDGE AND UNDERSTANDING

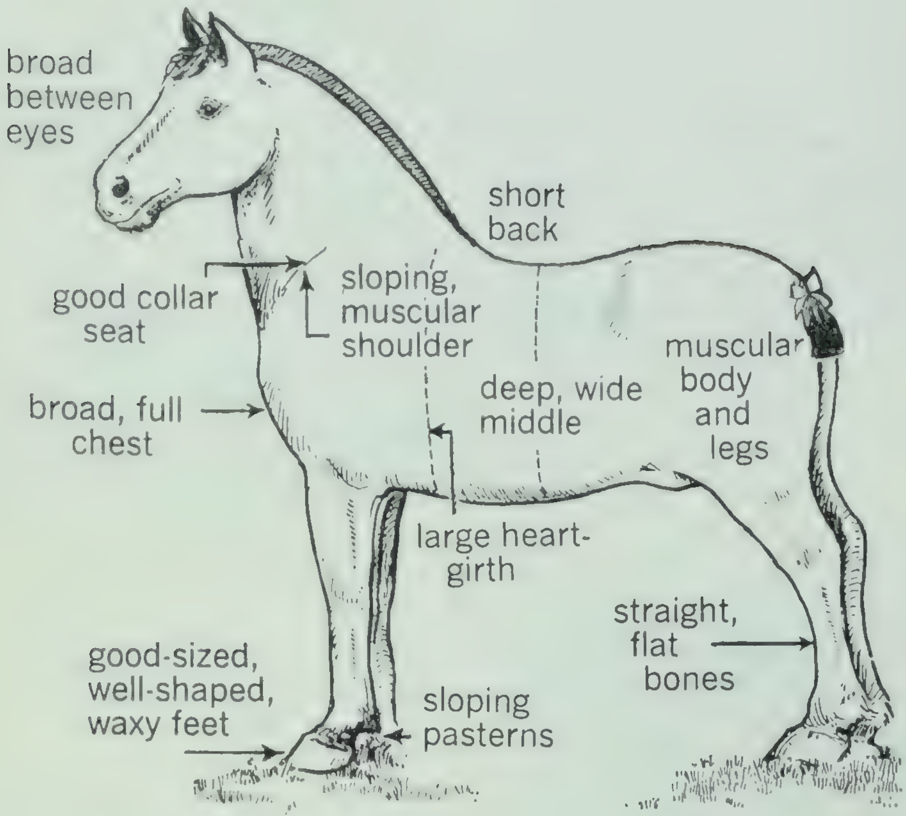
1. Describe a high-quality beef animal.
2. How can we identify the three beef breeds?
3. Dairy Shorthorns are dual-purpose cattle. Explain.

LIVESTOCK FOR POWER, FIBRE, AND FOOD

While cattle are the most important kind of livestock raised on Canadian farms, several other kinds of farm animals make important contributions to farming. Horses supply farm-raised power; sheep produce mutton for food and wool fibres for clothing; pigs provide pork, ham, and bacon.

Horses for work and speed

More than a million years ago, the ancestors of the horse were little animals no bigger than a fox. They had spreading feet with five toes on each foot, enabling them to get a grip on the soft ground. They sought safety from enemies by running



The characteristics of a good draft horse. Why is each of these characteristics desirable?

away; also, they often had to travel long distances for food and water. As a result, horses gradually developed the qualities of strength, speed, and endurance which have made them so useful for pulling heavy loads and for carrying people from place to place.

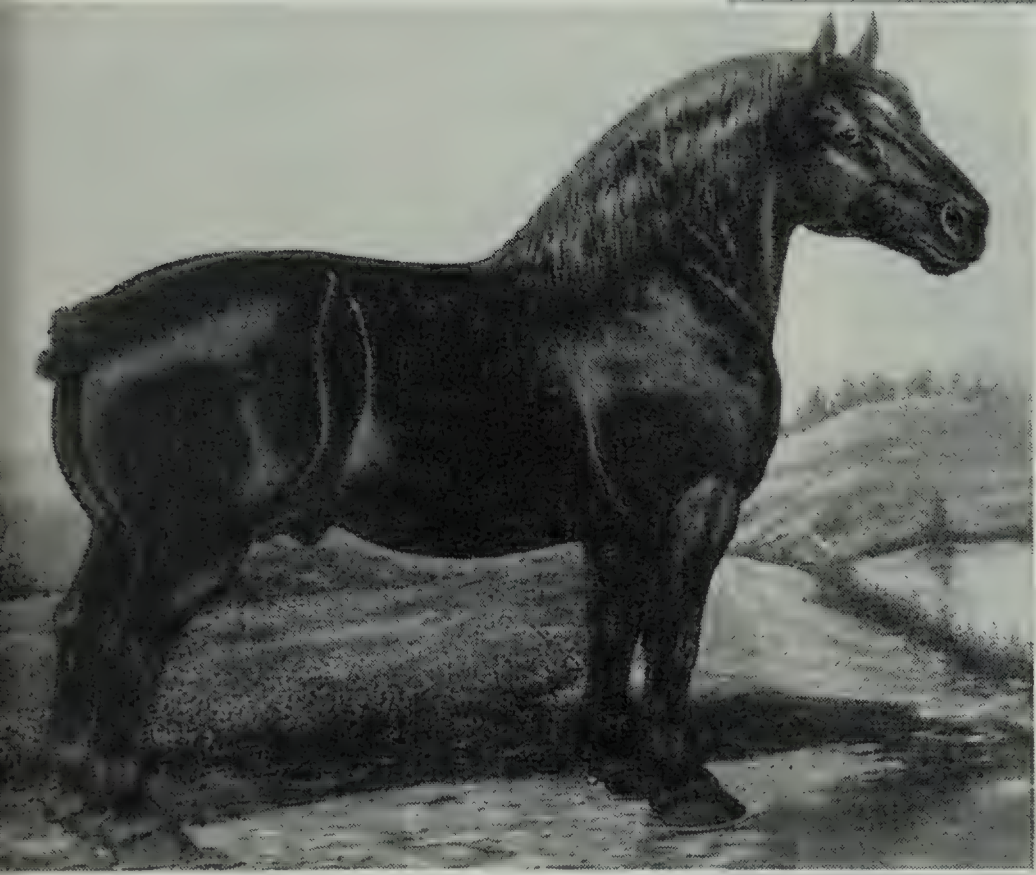
Man made wide use of horses long before the dawn of recorded history, first hunting them for their flesh, and later taming them for riding and for heavier work. For many centuries, horses were used extensively for warfare. In some countries, such as England and France, there was a need for strong horses to carry heavily armored knights. For this reason, heavy horses were selected and developed. From these heavy animals have come the *draft horses* of the present. In warmer lands, such as Arabia, warriors preferred *light horses* with great endurance and speed. In Canada, draft horses are used for heavy farm work. Light horses are often used for racing, driving, and riding.

A good draft horse is large, muscular, and fairly low-set. Its body should be broad and deep, with strong shoulders and firm, strong legs and feet. It should walk with a long, free stride.

Although many farms are completely mechanized with tractors and power-driven implements, there are others on which horses are still in use. Many farmers who continue to make use of draft horses take great pride in their animals, and practise maintaining and improving their quality.

In addition to draft horses, there are several breeds of light horses used for racing and driving. Trotters and pacers are usually *Standardbreds*, a

The Belgian, as its name suggests, was developed in Belgium. Belgians are bay, chestnut, brown, or roan. They have short, thick, massive bodies and thick, high-crested necks. (Saskatchewan Government photo)



The Percheron originated in France. This breed is usually black or dappled grey. These horses are well muscled and alert. (Ontario Agricultural College photo)

The Clydesdale originated in the Clyde Valley, in the lowlands of Scotland. "Clydes" are usually bay, brown, or black in color with white faces and white feet. The lower parts of the legs are covered with long, fine hair called *feather*. (Ontario Agricultural College photo)







Seven breeds of sheep raised in Canada (reading down from top left): The Oxford, Shropshire, Southdown, Hampshire, Leicester, Suffolk, and Rambouillet. Find one distinguishing feature of each breed. Which breeds produce long wool? (Ontario Agricultural College, Wool Bureau, Department of Agriculture, and Saskatchewan Government photos)

breed developed in the United States. The slender horses used in running races are *Thoroughbreds,* a very old breed developed in England. They are tall, slim, and handsome, and are the fastest of all horses. The term *thoroughbred* should be used only in referring to this breed of horses; many people apply the term wrongly to other livestock, when they should use the term *purebred.*

SOMETHING TO DO

1. Learn to recognize the three breeds of draft horses, preferably by studying them at a farm or a fair.
2. Find out if horses are used on farms in your area, and, if so, which breed is most popular.

Sheep for wool and mutton

Sheep-raising is a profitable branch of our livestock industry. Although sheep thrive best on good pasture, they can be profitably raised on land not suited for raising cattle; in fact, they often help to clear fields of weeds.

Sheep produce both wool and mutton. Canada's wool crop, while valued at several millions of dollars annually, does not supply all our needs for woollen clothing.

Since the time when shepherds first tended flocks of sheep, man has selected his stock to develop various types. For example, the *long wool type* produces an abundance of long, fine wool fibres, but is of little value for mutton. Most Canadian sheep are of the *mutton type,* and produce high-quality mutton as well as wool.

The body of a good mutton sheep resembles that of a beef animal – it is rectangular, wide, deep, long, low-set, and well fleshed, especially over the back, loins, and hindquarters. Why are these characteristics important? The fleece should be fine, dense, and fairly long; the wool fibres should have a fine crimp (wave), and a bright appearance, indicating an abundance of oil.

The chief breeds of sheep raised in most parts of Canada are the *Shropshire, Suffolk, Oxford, Southdown, Hampshire, Leicester (les′ter),* and *Rambouillet (ram′boo-lā).*

SOMETHING TO DO

Visit local fairs, or farms where sheep are raised, to learn to recognize breeds commonly raised in your area.

Pigs for bacon

Few, if any, animals have been improved as much as pigs. The long, trim *bacon type pig,* and the heavy *lard type* would hardly be recognized as descendants of the bony, ferocious wild pigs that were their ancestors.

Very few lard-type hogs are raised in Canada; this type is more commonly raised where corn, which is very fattening, is grown in large amounts. On the other hand, the bacon type is very extensively raised in our country. Both in Canada and in Great Britain there is always a good market for fine-flavored bacon with only a moderate amount of fat. Such bacon is produced only on long, trim hogs, that reach a weight of about 200 pounds at the age of 5 to 7

A high-quality Wiltshire side, produced by a Yorkshire hog. Bacon such as this sells readily on the British market. Notice the balance of lean meat and fat. (National Film Board photo)

months. The correct bacon type is illustrated in the diagram at the top of page 373.

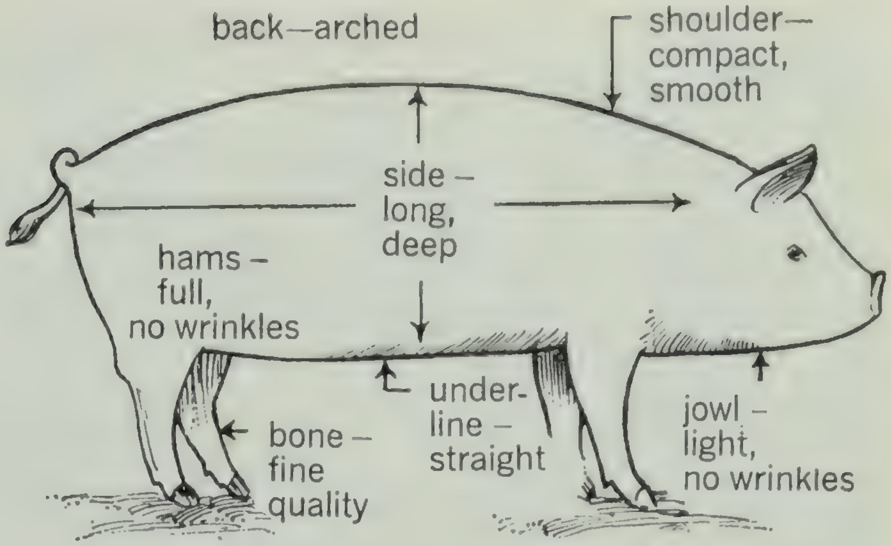
The *Yorkshire*, a trim, fast-growing, white bacon hog is by far the most popular breed in Canada.

At the Experimental Farm, Lacombe, Alberta, a new breed of bacon hog, the *Lacombe* has been developed. This white pig, with the characteristics of a good bacon type, is a valuable addition to Canadian agriculture, because this breed, when crossed with Yorkshires, produces hybrid offspring that are faster growing and more vigorous than either parent breed.

Scientific feeding is another important factor in developing select bacon hogs. It has been found that the addition of minerals and proteins to the diet of pigs greatly increases their rate of growth and improves their quality. At experimental farms, scientists are constantly testing the effects of various foods on the growth of pigs.

SOMETHING TO DO

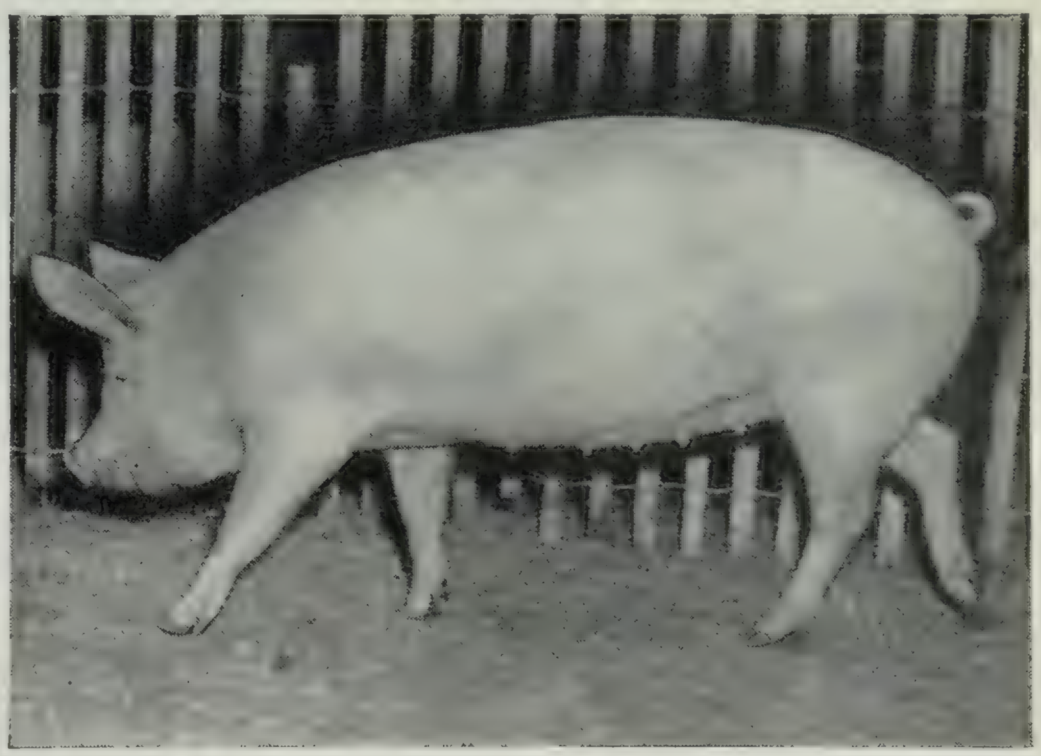
1. At farms and fairs, study the characteristics of *Yorkshires* and other bacon hogs such as the *Tamworth* (red), *Berkshire* (black with white nose, feet, and tip of tail), and *Lacombe* (white).
2. At a butcher shop, examine a side of pork. Compare the prices of ham, bacon, and roast pork, and locate these cuts of meat. Why must a select hog have long, deep sides?
3. At a feed store, obtain pamphlets in which you can read further about the effects of various foods on the rate of the growth of pigs.



The characteristics of a good bacon hog. A select bacon hog should weigh about two hundred pounds when it is marketed. Why is a long, deep side an important characteristic of a bacon hog?

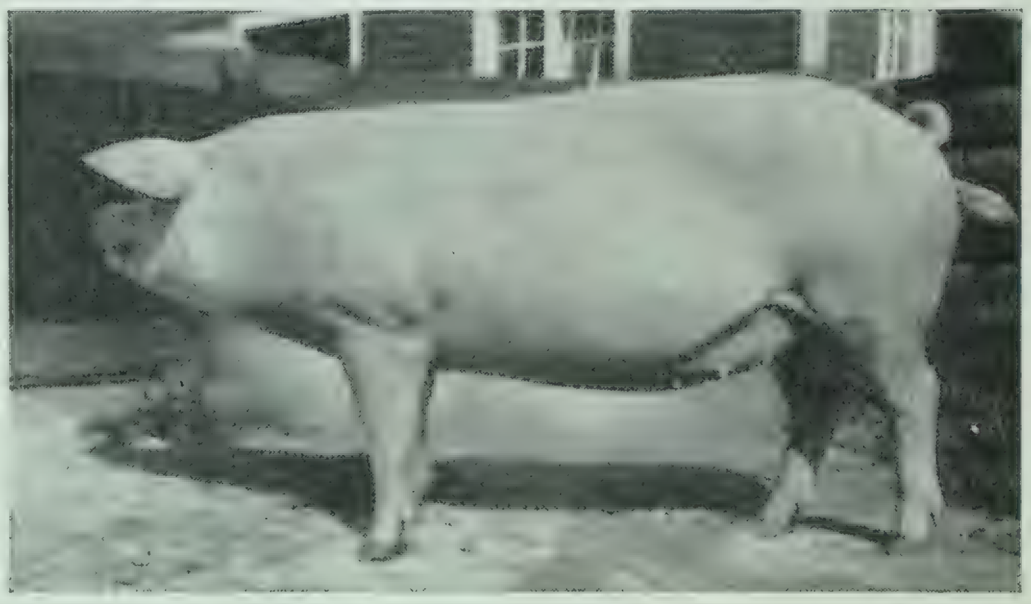
TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. What are the two *types* of horses? For what purposes were these types originally developed?
2. How would you identify the three common breeds of draft horses?
3. Describe a good mutton sheep. Name several common breeds.
4. Describe a good bacon hog.
5. Why has the Yorkshire become the most popular breed of bacon hog?
6. Why is the bacon type of hog the best type for Canadian farmers to raise?



The Yorkshire hog is the breed most commonly raised in Canada. Notice the white color, the great length and depth of the sides, the long, tapering hams, the straight underline, and the general clean - cut appearance. (Saskatchewan Swine Breeders Association photo)

The Berkshire hog is black, with white on the nose, feet, and tip of the tail. Why is it not a popular breed in Canada?



The Lacombe is a new breed, developed at the Lacombe Experimental Farm. This breed is a good bacon type, white in color, with long, deep sides. (Department of Agriculture photo)

POULTRY

The value of poultry products in Canada amounts to many millions of dollars annually. Eggs, a valuable part of a healthful diet, are the most important poultry product. In addition, chickens, ducks, geese, and turkeys are raised for meat.

Chickens are the most important class of poultry. They are descendants of the shy, wild, jungle fowl of India, and have been domesticated for a very long time. Many of the modern breeds were developed in England, China, the United States, and the countries along the north shore of the Mediterranean Sea.

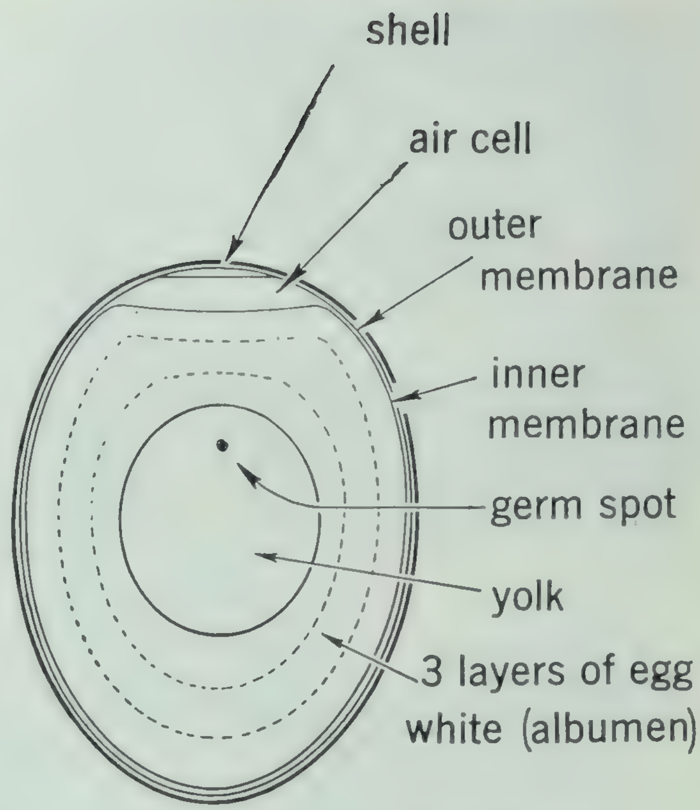
Like other domestic animals, chickens have been developed for special purposes. Some, such as the *White Leghorn*, are raised for the great number of large, white eggs they are capable of laying. The *Light*

Four breeds of chickens raised in Canada are (reading down from top left): The White Leghorn, raised for egg production; the Light Brahma, one of the meat breeds; the Barred Plymouth Rock and the Rhode Island Red, developed in America and raised to supply us with both large numbers of eggs and a plump body for meat. How can we identify each breed? (Ontario Agricultural College photos)

Brahma, a heavy meat-producing chicken, is commonly raised in some parts of Canada. Others, such as the *Barred Plymouth Rock, White Plymouth Rock, Rhode Island Red,* and *New Hampshire,* have large meaty bodies and also lay a large number of eggs.

Chickens are good examples of animals improved by man. The wild ancestors of the hen laid only 15 to 20 eggs each year, only enough to hatch a flock of chicks. After man domesticated these birds, fed them a better diet, and protected them from the weather and their enemies, and removed eggs from their nest to discourage setting, he found that some hens laid 30 to 40 eggs yearly. By hatching the eggs from these more productive hens, and again selecting the hens that laid the largest numbers of eggs, man has gradually developed hens that today lay over 300 eggs a year. In fact, any hen that lays fewer than 150 eggs annually is now considered to be unprofitable as an egg producer.

The poultryman knows the importance of a well-balanced diet for his flocks. Modern science has greatly improved the foods used on poultry farms. Suitable foods for chicks and laying hens must include minerals and large amounts of body-building and egg-producing proteins. In addition, hens must have constant supplies of clean water, oyster shell for the formation of egg shells, and grit to help the birds digest their food. Hens are raised and fed so that they lay as many eggs as possible in the fall and winter months, when the price of eggs is high.



The parts of an egg. Locate these parts, first by holding an egg up to a strong light so that you can see through it, and then by examining an egg opened into a saucer.

The parts of an egg

Eggs are valuable food because the egg white and yolk contain an abundance of easily digested protein. An egg is designed by nature to serve as a home and as a food supply for the chick which develops from the *germ* on the yolk of the fertile egg.

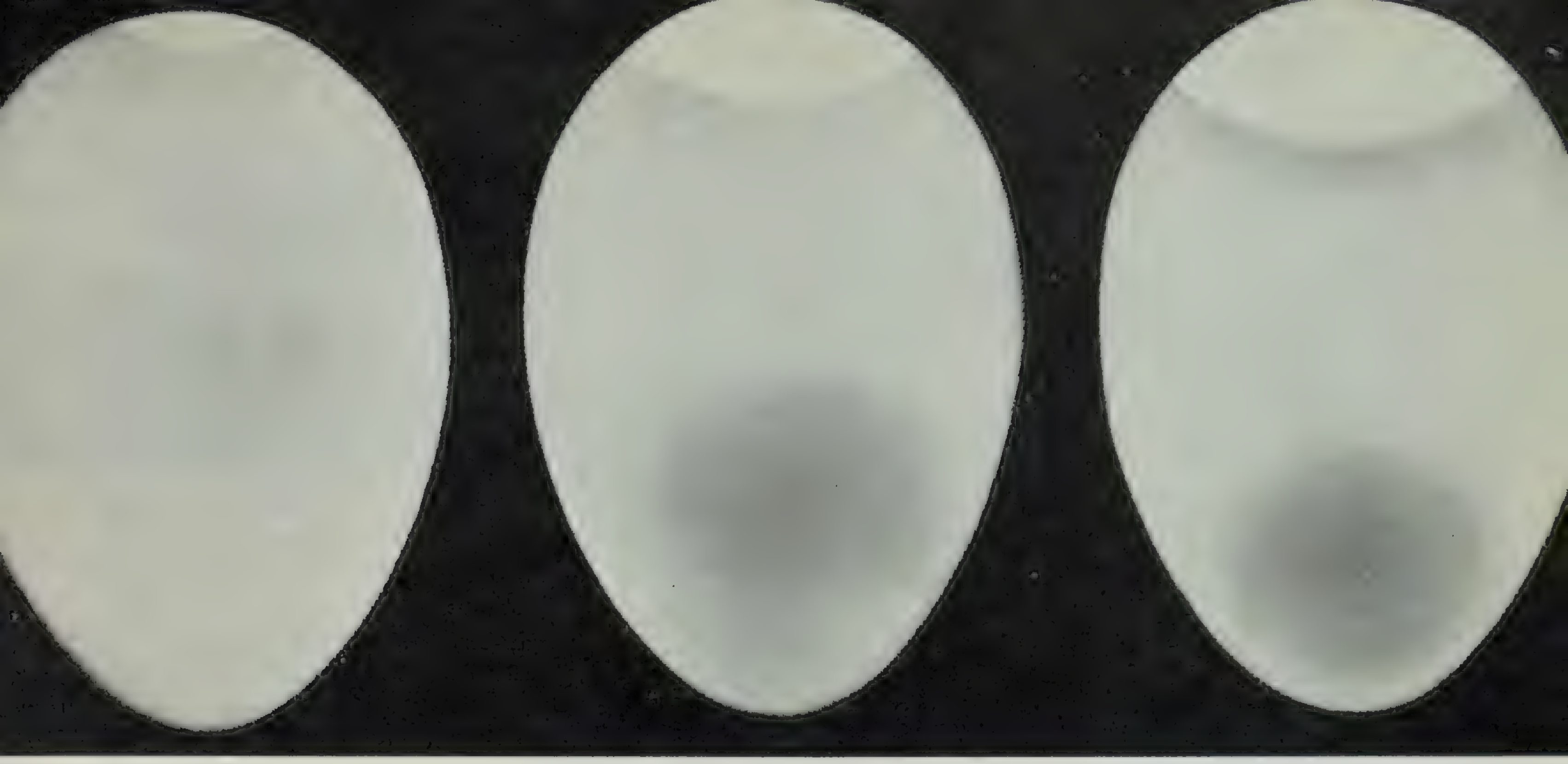
SOMETHING TO DO

Study the illustration on this page to find the parts of an egg. Carefully open a hen's egg and pour the contents into a saucer to find the parts shown in the illustration.

How eggs are graded

The sale of eggs is now carefully controlled by the government to protect the customer from buying inferior eggs. When you purchase eggs at a store, you should find on the carton a sign telling you the grade of the eggs being offered for sale. This is required by law. The grade will tell you the quality and size of the eggs. In order to determine the grade, the eggs have been *weighed* and *candled. Grade A Large* eggs weigh at least twenty-four ounces per dozen. Candling is done in a dark room by holding each egg in front of a hole in a box containing a light. The light passes through the egg, making its contents fairly visible. The *air cell* in Grade A eggs should be very small; the yolk should be in the centre of the egg, and should be indistinct. As an egg becomes stale, the air cell grows larger, and the yolk becomes darker.

Eggs should be gathered several times a day to prevent soiling of the shells. They should be kept in a cool



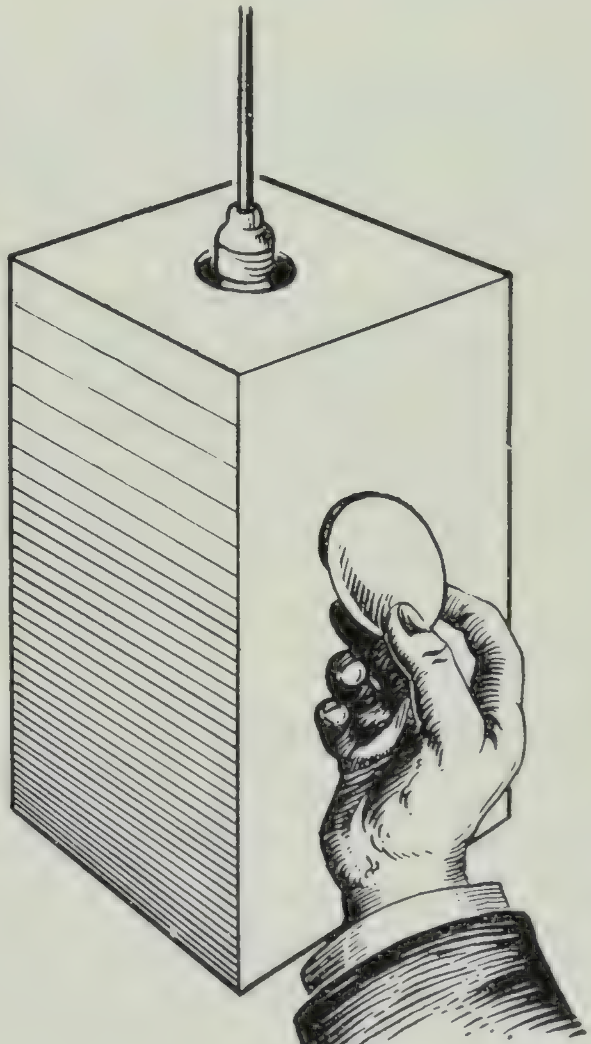
Example of eggs as they appear in candling. Left: Grade A, a fresh egg, as indicated by the indistinctness of the yolk and the small air cell. Centre: Grade B; notice the slight visibility of the yolk and the larger air cell. Right: Grade C, a stale egg with the yolk sunken and distinct, and a large air cell. (Department of Agriculture photo)

room that is free from strong odors, and should be sold as soon as possible. In your home, you can safeguard the quality of eggs by keeping them in a refrigerator or other cool place.

SOMETHING TO DO

1. Send to the Publications Branch, Department of Agriculture, Ottawa, for a chart illustrating the Canadian Standard Grades of eggs. This chart may be obtained free of charge. Have your teacher check your letter. *Each class should send for only one chart.*

2. Using a cardboard box, and a small electric light, construct an egg candler, as shown at the right. Use it in a dark room. Obtain specimens of various grades of eggs, or set aside eggs at intervals before you are ready to do this exercise, so that you will have fresh eggs and others of various ages. ***Caution:*** *To avoid the danger of fire, do not leave the light burning for more than a few minutes at a time.*



An egg candler that you can easily make. Be sure that the hole in the box is in line with the light bulb inside.

Bronze turkeys and White Pekin ducks. Turkeys and ducks are important sources of meat. Turkeys thrive best when the pens and range are clean and dry. Ducks like water for swimming, but will thrive in a dry location if given a suitable diet and plenty of water to drink. (Ontario Agricultural College photos)

Candle your eggs, comparing their appearance with those shown on page 377. Then break them into clean saucers and compare the appearance of the contents of the various grades.

3. Compare the grades of eggs offered for sale in a store. What are the differences in price? Weigh a dozen eggs of each *size* and find out which size offers the best value.

4. Visit a local hatchery to see a large incubator in operation. Find out the characteristics of the eggs selected for hatching.

5. Set up a small incubator at school. Before putting eggs in it, be sure that it is operating perfectly so that the temperature stays between 99° and 103°. Take turns tending the incubator. Before the chicks hatch, find out from a poultryman the care and food they need, and set up a small brooder for keeping them warm.

Dressed poultry grades

In some stores, dressed poultry offered for sale is tagged, showing the grade. Dressed poultry intended for export must be graded and packed according to government standards. The Canadian government grades for dressed poultry are as follows: Grade Special (or Grade Special Milkfed in the case of chickens); Grade A (or Grade A Milkfed in the case of chickens); Grade B; Grade C; Grade D.

Poultry that are graded *Special* are "commercially perfect specimens as to conformation, finish, plumpness, and fine soft quality of fleshing." The other grades include birds that are of poorer quality as a result of finish, discoloration from improper bleeding, and having too many pinfeathers, bruises, torn skin, and crooked breast-bones.

The term *milkfed* as applied to chickens refers to top-quality fowl that show the right amount of fat and a fine, soft texture in the skin. All chickens that have been fed milk do not necessarily grade "milkfed." To grade "milkfed," they must be finished by proper feeding, preferably in crates or pens. Chickens grading "milkfed" have an attractive appearance and a fine, delicate flavor.

SOMETHING TO DO

Send to the Publications Branch, Department of Agriculture, Ottawa, for regulations respecting *The Grading and Marketing of Dressed and Eviscerated Poultry*. Plan a trip to observe the grading of eggs and poultry.

Dressed poultry must be graded and displayed in an attractive manner in order to command the highest price on the market. How does society benefit from the grading of dressed poultry? (Department of Agriculture photo)

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. Explain why chickens today are evidence of the fact that "man has improved domesticated animals to supply society with useful products."
2. Name two breeds of chickens and tell the purpose of raising each of them.
3. How are eggs candled? Of what importance is this process?
4. Make a drawing showing the parts of an egg.
5. How can we safeguard the quality of eggs: (1) on the farm, (2) in the home?

HONEY-BEES

The honey-bee is another animal domesticated by man. The keeping of bees has been improved so that they supply mankind with greater quantities, and a better quality, of their delicious product, honey. As early as Biblical times, man raided the storehouses of wild bees for this natural sweet, and raised colonies of bees in hives made of straw. Today, bee-keepers raise their colonies of bees in rectangular wooden hives where they have plenty of room for rearing large broods of young, and for storing a quantity of honey. Another advantage of the modern hive is that boxes of honey can be removed without upsetting the routine of the hive. The modern bee-keeper saves his bees much of the

A modern apiary, placed in an orchard where the bees can secure honey from the blossoms. The bees also pollinate the tree flowers. How is this service useful to the farmer? (Department of Agriculture photo)

work of making honeycomb by providing them with frames of foundation comb on which they build their honey-cells.

You will find much to interest you in the story of bees. It is a story that, as yet, is known only in part. There is still much to be learned about these remarkable insects and the way they live and work. The more we know about them, the more we marvel at the wonderful things they do. Such amazing facts as the following are already known concerning the habits of bees: a queen bee can lay 3000 eggs in a single day; only the inhabitants of a hive are permitted to enter it; the honeycomb is a superb feat of engineering skill.

SOMETHING TO DO

The best way of learning more about bees is to observe them in one of the following ways:

1. Watch a bee at work in your flower garden or in a clover field. Do not excite or anger her, and she will not sting you. Observe how she secures nectar with her long tongue. Notice that her body becomes covered with pollen. As she goes from flower to flower, she performs the very important work of carrying pollen, which must be transferred from one flower to another so that the flowers can produce seeds. Sometimes you can see the bee gathering the pollen from her body into the *pollen baskets* on her hind legs. This pollen is carried back to the hive. Watch the *antennae* or feelers of a bee that has just arrived at a flower. With them she smells the nectar in the flower.

2. In order to observe a bee more closely, catch one in a small jar by placing the jar beneath a bee on a flower, and gently placing the top on the jar. Release the bee after studying it.

3. Bees may be kept for a day in a suitable cage. In a flower-pot, place some sod in which clover blossoms are growing. Press a glass chimney or a cylinder of screen into the sod, and cover it with cheesecloth. *Do not neglect these insect prisoners, and after studying them set them free uninjured.* If you put a few drops of honey or syrup in the cage, you will be able to see the bees feeding.

4. If possible, visit a local apiary to see how a bee-keeper looks after his bees. Do not go near the hives unless the owner is with you.

5. Examine some honeycomb. Notice the shape and arrangement of the cells.

A worker bee carrying pollen on its hind legs.

A suitable cage in which to keep bees, grasshoppers, and other insects for study.

6. Examine a dead bee to find its body divisions and the structure of its legs and wings.

How bees are adapted for their work

By examining the body of the bee, you probably noticed that, like all insects, bees have three body divisions: *head, thorax,* and *abdomen.* Which parts are covered with tiny hairs? To what part are the wings and legs attached?

On the bee's head you can find its two large *compound* eyes. Near the top of its head are three tiny *simple* eyes.

The bee's *mouth parts* form a slender, hollow tube for sucking up nectar. Why is the tube so long?

A bee has two pairs of *wings,* but the two wings on each side are joined together by tiny hooks, making it appear that the bee has only one pair. The wings of old bees are frayed at the edges. It is little wonder that they are worn, considering the many miles a bee must fly, and the heavy loads she carries.

As you have observed, bees have three pairs of legs. On the hind legs may be found the pollen baskets, tiny hollows surrounded by strong hairs. Bees bring *pollen* as well as *nectar* to the hive. Both serve as food for the young bees, and the nectar, after some of the moisture in it has been evaporated, is stored as *honey* to be eaten during the long, cold winter.

Bees could not protect their honey from bears, skunks, and mice if Nature had not provided them with stings. The sting is a sharp, barbed weapon which opens a tiny wound and pumps poison into it. When the worker bee uses her sting, it is torn away from her body, and the bee dies.

The kinds of bees in a hive

In the hive are three kinds of honey-bees: the *queen,* the *workers,* and the *drones.*

The queen is the largest bee in the hive. Her body is long and slender and extends far beyond the tips of

Above are the three kinds of bees in a hive, shown twice their natural length. From left to right they are a worker, a queen, and a drone. How can you tell them apart? A worker bee is shown natural size, at the left. (Department of Agriculture photos)

her wings. She is the mother of the hive and lays all its eggs. She can lay as many as 3000 eggs a day, actually twice her own weight! The one queen in each hive is carefully tended by a group of workers.

The workers, which are imperfectly developed females, may number from 10,000 to 100,000 or more in a hive. They are smaller than the queen and the drones. They do all the work of the hive – guarding it, keeping it clean, gathering honey and nectar, making wax and building honeycomb, feeding the queen and young bees, and making honey in preparation for the future.

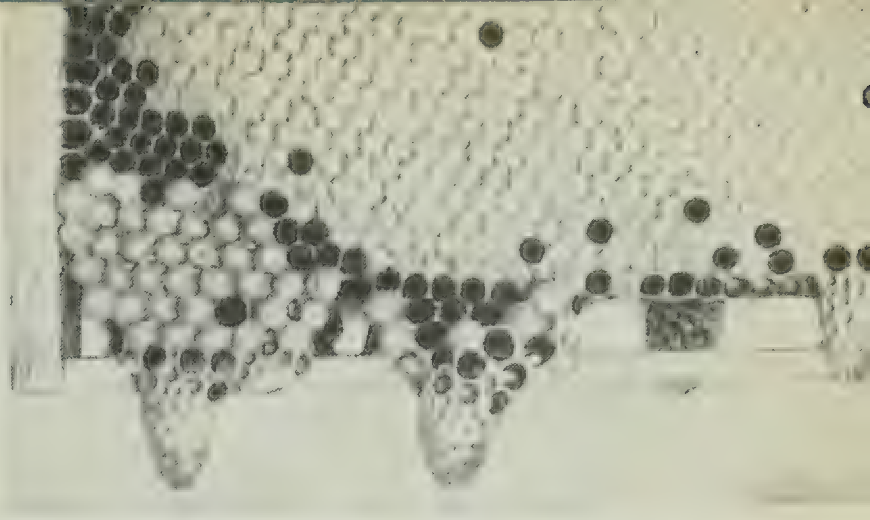
The drones, the male bees, are larger than the workers, and have a broad, blunt shape. They have no stings or pollen baskets. They do not help with the work of the hive. In the fall, when the supply of nectar becomes scarce, the drones are driven out of the hive, and are left to starve.

Life and work in the bee-hive

The bee-hive is a marvel of organization, industry, and cleanliness. There is no loafing by the queen or the workers, and there is no quarrelling. Every bee seems to know what she has to do.

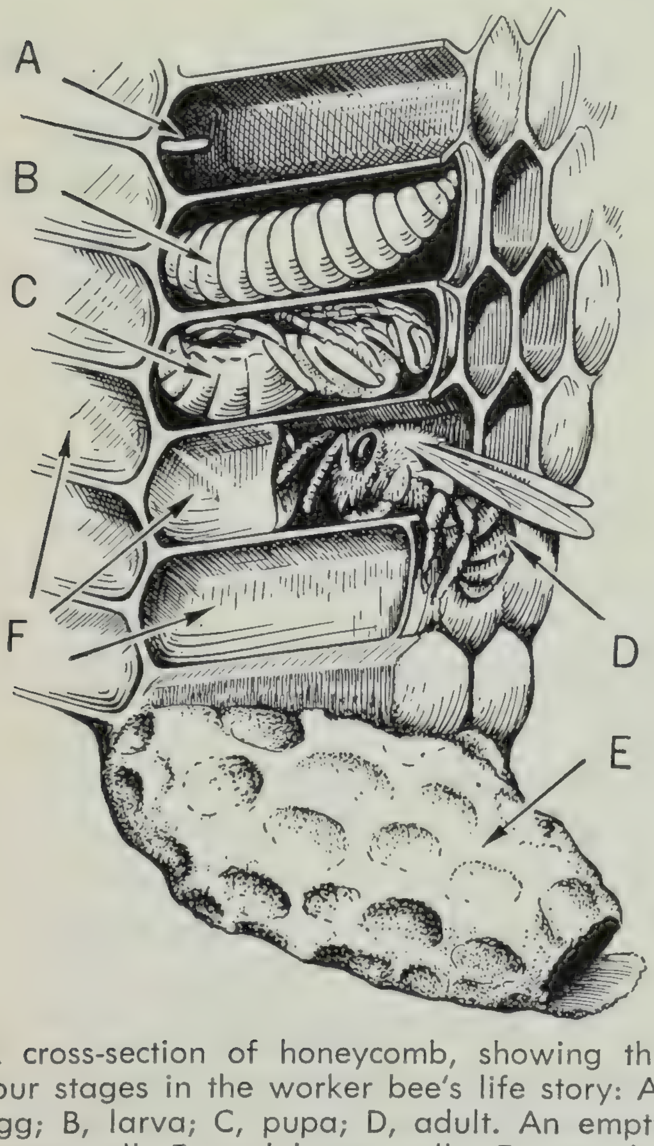
The honeycomb, the home of the young bees and the storehouse for the honey, is a wonderful structure. In building honeycomb, some bees gorge themselves with honey and secrete flakes of soft wax from the underside of the abdomen. The wax is chewed by other bees and then is molded into the right shape. Each cell is six-sided. The size of the cells is determined by the kind of bees that are to develop in them. Small cells are built for the storage of honey,

and as nurseries for worker bees; larger cells are made for baby drones; still larger, specially constructed cells are prepared for the eggs that are to develop into queens.



A frame of honeycomb in which open and capped worker cells are seen in the top half. The larger open and capped cells near the lower left-hand corner of the frame are drone cells. Two queen cells hang from the lower edge of the frame. (Department of Agriculture photo)

Study the illustration shown below to learn the stages in the life story of the worker bee. The egg hatches in three days, and becomes a white, legless *larva*. It is fed by other workers for six days. Then the cell is capped over by the workers, and the larva becomes a *pupa*. Now a remarkable change takes place. At the end of twelve days there emerges from the cell an *adult* worker bee, with four wings, six legs, and the other body features that we have observed. Almost at once this worker bee begins her share of the work in the hive.



A cross-section of honeycomb, showing the four stages in the worker bee's life story: A, egg; B, larva; C, pupa; D, adult. An empty queen cell, E, and honey cells, F, are also shown.

Bee-keeping is a profitable industry if the bee-keeper takes good care of his bees. He must supply them with clean, modern hives, inspect them for diseases, place them in warm quarters for the winter, and give them extra food when it is needed to replace the honey that is removed from the hive.

Honey is one of the finest of foods. In Canada, most of our top-quality honey comes from flowers in the clover family.

Many farmers realize that bees are even more valuable in pollinating flowers than in producing honey. Fruit-growers often keep a few hives of bees to improve the pollination of their fruit blossoms; others rent hives for the blossom season. Fruit trees, clover, tomatoes, and many other crops produce more fruit and seed in areas where there are several hives of bees. People who kill bees do not realize how useful and necessary these busy insects are.

TEST YOUR KNOWLEDGE AND UNDERSTANDING

1. Describe a worker bee under the following headings: body divisions, eyes, antennae, legs, wings, sting.
2. Tell the life story of a worker bee, making certain that you name its four life stages.
3. List five kinds of work performed by worker bees.
4. What are the three kinds of bees found in a hive? How can we tell them apart?
5. "To some farmers, bees are more valuable in ensuring the crop of fruit and seed than for honey production." Explain this statement.

WHAT HAVE YOU LEARNED?

IMPORTANT SCIENCE IDEAS AND UNDERSTANDINGS

A

1. The ancestors of domestic animals were once wild; in this state they were very different from the useful animals that are raised today.
2. For many centuries, farmers have improved their domestic animals by selection, scientific breeding, and better feeding.
3. The best animals in each breed may be selected by their size and appearance, and by the amount and quality of the useful products they provide.
4. By crossing two breeds of animals in the same class, it is possible to develop animals possessing the desirable qualities of both parents.
5. Animals raised for the same purpose belong to one *type;* within each type are several *breeds.*
6. The ability of the dairy cow to change grass, grain, and water into milk makes it our most useful domestic animal.
7. Milk is often called "the most nearly perfect food," because it contains large amounts of water, carbohydrates, proteins, fats, and minerals, and is an important source of several vitamins.
8. Milk that is offered for sale should be pasteurized to destroy any disease bacteria that may be present.
9. Beef cattle have rectangular, box-like bodies, capable of producing a maximum amount of top-quality meat.

10. In Canada, horses are raised as sources of farm power and for recreational purposes such as racing and riding.

11. Mutton-type sheep produce considerable wool in addition to well-fleshed carcasses.

12. Yorkshires are the most common bacon hogs in Canada because they produce a neat, trim bacon carcass with long, deep sides.

13. Some chickens are raised because of their high egg production; others are raised for meat; others are raised for both eggs and meat.

14. Eggs are usually graded for size and quality before being sold.

15. The honey-bee is useful both for pollinating flowers and for making honey.

16. Livestock benefit a farm in many ways in addition to the direct sale of farm products.

(a) The foregoing sentences are all true statements of important science ideas and understandings. Read and discuss them carefully as a review of this chapter.

(b) The following sentences describe situations in which some of these ideas apply. To test your ability to apply ideas to actual situations, match sentences in A with situations in B to which they apply.

B

1. When Walter was looking at a farm magazine, he found a picture of a Holstein cow which produced, during the previous year, a daily average of eighty pounds (thirty-two quarts) of milk.

2. Mr. Blake found that by adding barnyard manure to his fields, he was able to increase the yield from his crops.

3. Canada's Food Rules state that children should drink at least one pint of milk a day, and that teen-agers should drink one and one-half pints of milk daily.

4. When Frank and Peter visited Mr. Sharpe's dairy farm at milking time, they found him recording the weight of the milk produced by each cow. Mr. Sharpe told the boys that he also kept a record of the butter-fat test of each cow's milk.

5. Johnny Grotski's uncle, who has a large fruit farm, rents a few hives of bees while his trees are in blossom.

6. At the fair, Walter noticed that all the dairy cattle were similar in their general shape and appearance.

7. Tony was showing Gary some Leghorn hens. "Most of these hens lay an egg every day," said Tony. Gary remarked, "I don't think the hens would be very good to eat. They don't look fat enough."

8. Tests have shown that bacon hogs will reach market weight a month earlier, and at less cost, by the addition of certain minerals and vitamins to their diet.

IMPORTANT SCIENCE TERMS

A

selection	purebred	albumin
cross-breeding	grade	butter-fat
dairy cattle	whey	carbohydrates
beef cattle	pedigree	pasteurization
draft horses	inherit	air cell
bacon hogs	trap-nest	nectar
mutton sheep	casein	pollen

To show that you understand and can use the science terms listed in A, match with the situations described in B those terms which apply.

B

1. When milk sours, it separates into a watery liquid and a thick material used in making cheese.

2. Gordon Pearson's father bought a Jersey cow. Its ancestors for many generations had been Jerseys.

3. Walter Emery obtained papers that showed the ancestry of the Cocker Spaniel pup that his father bought for him.

4. Most animals, when they are fully grown, have an appearance similar to that of their parents.

5. When Peter Stevens spent a day at his uncle's poultry farm, he noticed that each hen had a numbered leg band. He also observed that his uncle kept a record of the number of eggs laid by the hen bearing each number.

6. When Donna Kubo was boiling milk to make hot cocoa, a thin film appeared on the surface of the milk.

7. Bill Curtis and Gerald Gingerick were candling eggs. Bill said, "I can tell that this egg is stale because it has a big 'empty' space at the larger end."

8. Honey-bees make much of their honey when clover plants are in blossom.

In the drawing above the artist has shown a honey-bee on a clover plant. The photograph at the right shows a honey-bee on alfalfa blossoms. (Department of Agriculture photo)

SCIENTIFIC METHOD AND ATTITUDES

1. Two farmers were discussing ways of choosing suitable brood sows (female pigs to be kept to raise litters of young pigs). One of them recalled that the experimental farm recommended that they keep the sow that grew most rapidly and was the best bacon type, so that these qualities would be inherited by her offspring. The second man disagreed with this advice. "I don't care what they say at the experimental farm. I believe in finding out for myself. I always keep a runt for a brood sow. (A runt is the smallest pig in a litter, and usually grows slowly.) I have two good reasons for keeping a runt; first, you can get your money sooner if you sell the first pigs to reach market weight; second, a few years ago I had a runt brood sow that had a litter of ten fine pigs."

(*a*) How was the second farmer's method of selection different from the method employed by scientific farmers?

(*b*) What scientific attitude did he seem to lack – curiosity, open-mindedness, looking for natural causes, or basing thinking on facts? Explain.

(*c*) Do you think his two reasons for his method of selection were good ones? Why?

2. A poultryman wondered why his hens laid more eggs in summer than in winter. After thinking about differences in the food, habits, etc. of hens in summer and winter, he decided that the greater summer egg production might be due to the warmth, or to the longer days, or to differences in food, or to all of these conditions. He decided to test the effect of more light on the production of his flock. One fall he divided his flock into two equal groups, being careful to see that both groups were as alike as possible. Both groups were kept in identical pens placed side by side. The temperatures in both pens were checked daily and were usually found to be the same. Both groups were given the same types of food, which was placed in feeders from which the hens could eat their fill. Constant supplies of fresh water, grit, and oyster shell were maintained in both pens. The only condition that was different was that in one pen electric lights were turned on in the early morning and late evening, to make a total of four extra hours of "daylight" each day. In the other pen, no extra light was supplied. Careful records were kept of the number of eggs laid by the hens in each pen.

At the end of the winter, it was found that the hens that received extra light laid an average of four eggs a month more than those with no extra light. The hens that laid more eggs also ate more food than the other group. However, the total cost of the extra food and electricity was much less than the selling price of the extra eggs.

(*a*) What conclusion could be reached from this experiment?

(*b*) How might the farmer apply this new information?

(*c*) Show how the farmer followed the steps in the scientific method.

(*d*) What was the only condition that was different in the two groups? Why was the farmer so careful in making all other conditions similar?

(*e*) Do you think that the farmer has completely answered his original problem? Why? What condition might be tested the next year? How might this be done?

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